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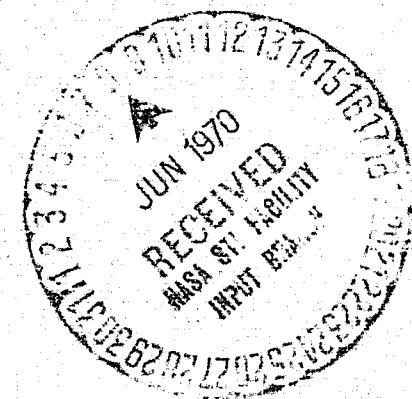
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APOLLO RCS POSITIVE EXPULSION TANKAGE
PRODUCT IMPROVEMENT PROGRAM
FINAL REPORT - TASK B

LONG TERM COMPATIBILITY TESTING

Bell Report No. 8514-928004
12 November 1969

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FOREWORD

This report is one of a series of task reports which present the results of a program performed by Bell Aerosystems Company during the period July 1967 through September 1969 under Contract NAS9-7182 for the National Aeronautics and Space Administration, Manned Spacecraft Center. Mr. Darrell Kendrick was Technical Monitor of the program for NASA. The Bell Aerosystems Program Manager was Mr. R. K. Anderson.

The purpose of the program was to improve and update the Apollo RCS positive expulsion propellant tank assemblies in the areas of performance, reliability and mission duration. The program effort was divided into the following major tasks, each of which is reported separately:

Task A - Historical Summary Report - A chronological summary of the evolution of the Command, Service, Lunar Module and other related tankage was prepared. This summary includes data on all configurations considered under the applicable programs and describes related IR&D work at Bell Aerosystems.

Task B - Long Term Compatibility Testing - The purpose of this task was to determine the useful operating lifetime of the Apollo Configuration RCS tanks as applicable to a mission of extended duration with a specific goal of 12 months. This task consisted of the following sub-tasks:

B-1: Tank Assembly Storage: Three tank assemblies were stored with propellant (N_2O_4 , MMH, 50/50 fuel blend) for 12 months at operating pressure. At the end of this time each tank was subjected to a complete propellant expulsion followed by disassembly and evaluation.

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B-2: Bladder Material Compatibility Testing: Teflon bladder material specimens were subjected to rolling of buckled fold tests after 24 hours, six months, and 12 months exposure to N₂O₄, MMH and 50/50 fuel.

B-3: External Flange Seal Evaluation: The effect of initial flange bolt tightening and retightening techniques on the rate of torque decay during a one-year shelf storage period was evaluated.

Task C - Correlation of Referee Fluid and Propellant in Vibration Testing - The objective of this task was to verify that vibration testing of the Apollo type bladder with referee fluid is representative of vibration testing with actual propellants. To develop a correlation with sufficient accuracy, the following three areas of testing were pursued:

C-1: Vibration tests were conducted with referee fluid in a plexiglass tank to define the response characteristics of the bladder as affected by ullage level, direction of excitation and vibration input level.

C-2: Rolling of buckled fold tests were conducted on bladder material specimens to compare endurance in referee fluids with endurance in propellants.

C-3: Full scale vibration testing was performed on a Lunar Module RCS oxidizer tank with N₂O₄.

Task D - Elimination of Permeation and Bubble Formation - The objective of this task was the elimination or reduction of bladder permeation and the associated problem of bubble formation within the bladder. This task included two principal areas of effort:

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- D-1: Development of Permeation Barrier: This sub-task consisted of design and fabrication of a Teflon bladder with an aluminum foil laminate as a permeation barrier. This bladder, which was of the Service Module oxidizer configuration, was also designed to function in an undersized configuration.
- D-2: Elimination of Bubble Formation in Current Apollo Bladder Configuration: Experiments were conducted on both model and full-scale tanks to examine bubble formation phenomena as a function of such variables as temperature, pressure and ullage level. Data from these tests were used to provide an empirical basis to better understand the mechanisms involved and the effect of each on bubble formation.

Task E - Solution of Command Module and Service Module Oxidizer Repositioning Problem - The objective of this task was to increase expulsion cycle life of these bladders by eliminating damage due to post-expulsion repositioning.

- E-1: Service Module Oxidizer Bladder: The approach used to solve this problem was the use of an undersized configuration similar to that used on the Lunar Module RCS tanks to solve the same problem.
- E-2: Command Module Bladder: This problem was associated with the twist mechanism involved in a horizontally mounted tank during the fill cycle. A solution to this problem could not be found within the constraints of the program.

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Task F - Integration and Verification of Solutions - The objective of this task was to devise a series of formal tests to demonstrate compliance of design changes from Tasks D-1 and E with the requirements of the applicable Apollo contractor procurement specification.

Service Module oxidizer bladders of the undersized configuration with an aluminum foil laminate were subjected to Qualification level vibration testing and were to be subjected to 20-propellant expulsion cycles. However, problems occurred during vibration testing which resulted in bladder failure and this task could not be completed within the limits of this program.

Since the Command Module bladder twist problem was not solved (Task E-2), no Command Module tank testing was performed in Task F.

This report covers the effort performed under Task B. The other major tasks are reported individually as follows:

<u>Task</u>	<u>Report Number</u>	<u>Title</u>
A	8514-927002	Historical Summary Report
C	8514-928005	Correlation of Referee Fluid and Propellant Vibration Testing
D	8514-928003	Elimination of Permeation and Bubble Formation
E	8514-928006	Solution of Command Module and Service Module Repositioning Problems
F	8514-928007	Integration and Verification Testing

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FINAL REPORT : TASK B : LONG TERM
COMPATIBILITY TESTING

I. INTRODUCTION

The objective of this task was to determine the useful operating life of the current Apollo and LM RCS tank configurations (Refer to Figure 1) applicable to an extended duration mission with a specific test requirement for a 12-month storage period with propellant at operating pressure and temperature.

Particular aspects of the current tank configurations which were thought that they could be possibly affected by extended storage with propellant were:

1. Creep of the titanium tank shell
2. Integrity of the external tank flange seal with respect to possible cold flow of the teflon gasket and subsequent loss of bolt torque.
3. Possible degradation of bladder material because of prolonged exposure to propellant.

In addition, long term compatibility of N₂O₄, MMH and 50/50 fuel blend with the combination of materials in the tank assemblies was to be verified.

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II. SUMMARY

One year exposure to MMH, N₂O₄ and 50/50 fuel blend at operating pressure and temperature had no adverse effect on tank assemblies of the Apollo/LM RCS tankage configuration from the standpoint of material compatibility, structural adequacy, expulsion performance capability or external tank flange seal integrity.

Exposure of Apollo teflon bladder material to MMH, 50/50 fuel blend and N₂O₄ for one year had no measureable effect on the bladder material as evidenced by no change in the roll fold cycle life of 425 specimens after 24-hour, 180-day and 365-day storage periods in the propellants.

One year shelf storage of Apollo/LM external tank flange seal configurations resulted in no measureable tank flange bolt torque decay and no helium leakage at 360 psig.

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III. DISCUSSION

A. Task B-1 : One-Year Tank Storage Program

1. Test Description

The test units consisted of one Lunar Module oxidizer tank assembly (LMO), one Lunar Module fuel tank assembly (LMF), and one Apollo Command Module oxidizer tank assembly (CMO), which were filled with N₂O₄, 50/50 fuel blend and MMH, respectively. The pressurant gas was helium. The tank assemblies, which were supplied by NASA-MSC, are described in Table 1.

The LM configuration was chosen for two of the tanks as a conservatism, since the undersized bladder would be subjected to more stress than a full size bladder during storage. All three tank assemblies were flight configuration production units and were re-acceptance tested prior to the storage test to confirm their integrity. The acceptance test of each unit was conducted in accordance with the established procedures for the particular configuration.

The tank assemblies were installed into the storage test system shown schematically in Figure 2 and pictorially in Figures 3, 4 and 5. The tank assemblies were stored in the vertical flange-up position to provide accessibility of the flange seal for leak checking and to subject the bladders to greater stresses during storage than they would experience in the horizontal attitude. The tanks were stored at nominal operating pressure and 70°F except that, once a month for the first six months of storage, the tank temperature and pressure were increased to the maximum operating conditions for a period of six hours to subject each tank to the maximum conditions of stress and propellant corrosiveness required in the applicable specification. Also, during

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the first six months of storage, propellant was expelled periodically from each unit until approximately 60% of propellant remained in each tank. The expulsions were performed to simulate propellant use during a mission. Samples of propellant and pressurant gas for chemical analysis were obtained at the same time the expulsions were made.

For the remaining six months of storage, the tank pressure and temperature were maintained at nominal operating pressure and 70°F so that the formation of gas inside the bladder could be studied. No determination of gas formation was made during the first six months. During the last six months of storage, X-rays of each tank assembly were obtained on a monthly basis to study gas formations inside the bladder.

Once a month during the 12-month storage period, each tank assembly was tested for flange seal gas leakage by using a helium mass spectrometer. Due to the length of the test period, strain gage measurements to determine tank shell creep were not made. Instead, each tank shell was measured both diametrically and longitudinally before and after the storage test.

At the completion of the 12-month storage period, each tank assembly was subjected to the following:

- (a) Propellant expulsion to full tank pressure differential (zero liquid pressure)
- (b) Bladder leakage test

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- (c) Tank assembly leakage test
- (d) Bladder removal and evaluation
- (e) Tank shell hydrostatic proof test

2. Test Results

The three tank assemblies completed the 12-month propellant storage period without incident. The monthly tank flange leakage tests revealed no leakage throughout the storage period.

The results of the pre-storage test acceptance test are contained in Table 2. As can be seen, there was essentially no change from the original acceptance test results which had been obtained approximately one year before the pre-storage acceptance test. Even though the tank flange bolt torque had decayed on each unit, there was no leakage at the maximum operating pressure. The flange bolts were re-torqued to the specification values of 60 in-lb.

Table 3 contains the propellant expulsion schedule during the first six months of the storage. Tables 4 and 5 contain the results of the chemical analysis of the propellant and pressurant gas samples obtained during the first six months and at the end of the test. As can be seen in these tables, the oxidizer tank had reached an equilibrium condition (N_2O_4 saturated with helium and gas side saturated with N_2O_4) in one to two weeks from the start of the test. The fuel tank propellants became saturated with gas during the first two weeks and saturation of the gas side with fuel vapors occurred during the first month of storage. The propellant chemical analyses also indicate that there was

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little or no degradation of any of the propellants during the one year storage period. One significant finding is that the NO content of the N₂O₄ did not change appreciably during the storage period, decreasing from a pretest value of 0.58% to a post-test value of 0.49% by weight.

It should be pointed out that the percent of helium in propellant and percent propellant constituents on the gas side, contained in Tables 4 and 5, can only indicate a trend towards saturation. This is based upon the wide variation in some of the values obtained. The variation is probably due to the inability to obtain a representative propellant or pressurant sample consistently.

The temperature and pressure time history for the 12-month storage period is shown in Figures 6, 7 and 8. During the stabilized temperature and pressure portion (last 6 months) of the storage test, it can be seen that the pressure varied approximately ± 30 psig and the temperature varied approximately $\pm 30^{\circ}\text{F}$. Detailed plots of minimum/maximum pressure and temperature for each day are contained in monthly charts in appendices I, II, and III.

X-rays of the tank assemblies revealed that the pressure/temperature variations in the last 6 months of the test caused gas to form inside the bladder. Since no X-rays were taken during the first 6 months and since it was not possible to determine the gas bubble volume formed because of the monthly expulsions, no evaluation of bubble size can be made for the first 6 months.

Table 6 indicates the gas bubble growth in each of the tank assemblies during the last six months of the storage period. As can be seen in the table, the gas bubble that formed in the LMF tank was much larger than the gas bubble formation in either the LMO or CMO tank. Although the

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final liquid level in the LMO tank was lower than that in the LMF tank, the X-rays revealed that the bladder folds in the LMF tank were much more relaxed than those in the LMO tank, thereby indicating a larger gas volume. The gas pocket in the CMO tank never progressed any further than the outlet tube and the bladder folds remained tight around the diffuser tube throughout the last six months of the storage period.

It is postulated that the gas formation in the tank assemblies was due to the numerous variations in temperature and pressure. Since the propellant was saturated with helium at the start of the last six months of the storage period, any downward excursions in temperature or pressure would force free gas out of solution. As the temperature and pressure increased, more helium would permeate through the bladder because the propellant was no longer saturated. This would occur since the gas bubble could not dissolve back into the propellant as fast as the permeating helium due to the smaller surface area of the bubble as compared to the exposed surface area of the bladder. As a consequence, the propellant would become saturated at the higher temperature and pressure and a portion of the initial bubble would remain since the propellant could not absorb any more helium. As further temperature/pressure changes took place, this process repeated itself, thereby causing the gas bubble to increase in size. Thus, it appears that during extended storage periods with an initially helium saturated propellant, repeated small temperature/pressure variations can cause a gas "pumping" action which may result in significant free gas formation inside the bladder.

As can be seen in Table 6, the CMO-MMH tank

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yielded in the smallest gas bubble volume and the LMF-50/50 tank yielded the largest. Since the solubility of helium in MMH or 50/50 is approximately the same, at first glance it would appear that the CMO and LMF tanks should have had equivalent gas bubble formation. However, when it is considered that due to the larger tank size and undersize bladder in the LMF tank, for a given period of time, the 50/50 fuel in the LMF tank would become saturated with helium much faster than the MMH in the CMO tank because more helium would permeate the LMF bladder. Evidently, the rate at which the helium was permeating the CMO bladder during upward pressure/temperature changes was less than the rate at which the gas bubble was re-dissolving in the propellant, thereby resulting in little or no bubble residual. The LMO bladder exposed surface area is greater than that of the LMF due to the greater tank length and it would appear that if the reasoning is valid for the differences in the gas bubble formed in the LMF and CMO tanks, a larger gas bubble should have formed in the LMO tank. However, this did not happen for two reasons:

The bladder, while saturated with N_2O_4 , undergoes a 1 1/2% linear swelling which tends to overcome its undersized characteristics.

The bladder, while saturated with N_2O_4 , becomes much more pliant and is therefore more easily held to the tank shell by the weight of the contained propellant.

These factors tend to decrease the permeating surface of the bladder when N_2O_4 is used. Fuel does not measurably affect the bladder material in this manner.

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Another possible factor was found during testing performed under Task D of this program, which is reported in Bell Report No. 8514-928003 "Elimination of Permeation and Bubble Formation." Results of these tests indicated that helium permeation through the bladder decreased when N₂O₄ was present as a counter permeant, while counter permeation of fuel did not seem to measurably affect helium permeation. Thus, during the rising portion of a temperature cycle, more of the entrapped gas would be able to go into solution in an oxidizer tank than in a fuel tank.

At the conclusion of the 12-month storage period the post-storage test evaluation revealed the following:

- (a) Expulsion Tests: One expulsion cycle was conducted on each tank assembly successfully at full tank pressure differential.
- (b) Bladder Leakage Tests: No indication of bladder deterioration (Refer to Table 7).
- (c) Tank Assembly Leakage Tests: An external leakage test was performed on each tank assembly with helium at maximum operating pressure using a mass spectrometer. No leakage was detected.
- (d) Bladder Assembly Inspection: No evidence of deterioration of bladder or diffuser hardware. (See Figures 10 and 11.)
- (e) Tank Shell Inspection: The lower half of the inside surfaces of both fuel tanks were mottled by a light blue-gray stain (as shown in Figure 9). The stained areas corresponded with the area of

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(e) Tank Shell Inspection: (Cont)

contact between the bladder and tank shell during the last six months of the storage period when the tanks were 60% full. Examination of the stains at 12X with a boroscope and surface replicas of the stains were merely discolorations on the surface of the shells with no effect on the shell material. No stains or deterioration were found on the LMO tank shell.

(f) Tank Shell Measurements: The length and diameter of each tank shell was measured to the nearest .001 inch and compared to measurements made prior to the start of the storage test. No change in dimensions could be detected thus indicating that no measureable creep had been experienced during the test.

(g) Proof Pressure Test: Each tank shell was subjected to a hydrostatic proof pressure test at the following pressures:

LMO	333 psig
LMF	333 psig
CMO	525 psig

No permanent set was encountered in any of the shells as a result of the proof pressure test.

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In summation, one year exposure to MMH, N_2O_4 and 50/50 blend at operating pressure had no adverse effect on tank assemblies of the Apollo/LM RCS tankage configuration from the standpoint of material compatibility, structural adequacy, expulsion performance capability or external seal integrity.

B. Task B-2 : Long-Term Bladder Material Compatibility Tests

1. Test Description

To supplement the one year tank storage program, rolling of buckled fold cycle life tests were conducted on bladder material specimens to determine the effect of propellant exposure on the Teflon material. The cycle life tests were conducted at 35°F and 70°F in N_2O_4 , MMH and 50/50 fuel blend after 1-day, 180-day and 365-day exposure to the propellants at 60°F to 80°F.

The rolling of buckled fold cycle life test was chosen as the evaluation test method because of its simulation of the basic bladder fatigue mode in vibration. Previous investigations have shown that vibration constitutes a critical bladder loading condition and that the rolling of buckled fold test simulates the type of damage induced in the Teflon material by vibration environments.

Test specimens measuring 1.5 inches by 14 inches were prepared from the cylindrical and hemispherical portions of the bladders listed in Table 8. Table 8 also indicates the distribution of the bladder specimens among the test periods, temperatures and propellants. A total of 425 specimens were prepared for test.

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Two high frequency (14 Hz) rolling of buckled fold test machines as shown in Figure 12 were designed and fabricated for fuel and oxidizer testing. Each machine was capable of testing five specimens simultaneously and was contained in a pressurized tank to provide for testing in propellants at temperatures above the propellant vaporization temperatures.

The rolling of buckled fold test parameters included the following: cyclic rate : 14 Hz; internal blade angle : 110°F; blade gap : 0.035 inch; buckled fold travel distance : 0.5 inch; specimen tension : 600 psi. The test temperatures of 35°F and 75°F were achieved by hot and cold fluid circulation through coils in the propellant reservoir. The cyclic rate of 14 Hz was chosen because it is the resonance frequency during vibration of an Apollo configuration tank. The rolling of buckled fold test consisted of the repeated cycling of the folded bladder material specimens over a pair of teflon coated inclined blades. The specimens were held in tension and moved back and forth over the blades by an electrically driven eccentric.

2. Test Results

The results of this test series as displayed in Table 9 revealed that exposure to MMH, 50/50 fuel blend or N₂O₄ for periods up to one year has no significant effect on Apollo teflon bladder material.

As can be seen in Table 9, a wide range of scatter exists in the data. However, this amount of scatter is not unusual for teflon bladder material and has been observed on past programs. Possible explanations for the

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scatter could include the following: 1) inherent variables in the test equipment 2) material variation in the test specimens.

One important result of the test series is that the cycle life of teflon bladder material in 50/50 fuel blend is equivalent to that in MMH and not significantly lower as was previously indicated during the NASW 1317 program. One explanation for this finding could be in the difference in the two test methods employed. On the previous program, the test specimens were not pre-soaked in the propellant prior to testing and they were removed for inspection at frequent intervals and returned for further cycling. On the present test series, the variability introduced by frequent handling of the specimens was eliminated because the specimens were cycled for a predetermined number of cycles before examination and were not returned for further cycling even if they had not failed.

It will also be noted in Table 9 that the cycle life in MMH or 50/50 fuel blend at 35°F and 75°F is significantly lower than in N₂O₄. This is as expected from past experience. It appears that oxidizer has a softening effect on the teflon material thereby increasing its cycle life.

It should be noted that although the rolling of buckled fold test is a useful method of comparing mechanical flexure life of one bladder material with another, it cannot be directly related to actual flexure life of a bladder in a functional or dynamic environment as part of a tank assembly.

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C. Task B-3 : External Tank Flange Seal Evaluation

1. Test Description

The objective of this task was to evaluate the adequacy of the present Apollo and LM tank flange seal for long term sealing capability under dry storage conditions. The tank flange seal configuration is identical for all Apollo and LM tanks. In the event that the present tank flange torquing procedure proved to be inadequate for long term dry storage, other bolt torque methods to reduce the cold flow of the teflon seal were also investigated.

The bolt torquing methods investigated were as follows:

Unit F-1 : Present acceptance test method:

Initial torque of 60 in-lb and 24 hour retorque to 60 in-lb.

Unit F-2 : 650 lb Solon compression washers placed under bolt heads to maintain torque. Initial torque of 60 in-lb with 24 hour retorque to 60 in-lb.

Unit F-3 : Initial torque of 80 in-lb with 2-hour retorque to 80 in-lb and 24 hour backoff to 60 in-lb.

Unit F-4 : Initial torque of 60 in-lb and 2-hour and 24-hour retorques to 60 in-lb.

The hardware used in the torque decay and dry storage tests were tank shells and diffuser tubes assembled without bladders as follows:

Unit F-1 : P/N 8330-471053-3 S/N 2

Unit F-2 : P/N 8330-471053-1 S/N 1

Unit F-3 and F-4 : P/N 8330-471053-1 S/N 2

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Units F-1 through F-3 were subjected to a one-year dry storage test at ambient (60°F to 80°F) temperatures. Periodically, residual bolt torques were determined and helium mass spectrometer leakage tests at 300 psig were performed. The torque method used on Unit F-4 did not show any significant improvement over Unit F-1 and as a consequence Unit F-4 was eliminated from consideration.

2. Test Results

Units F-1 through F-3 successfully completed the one year dry storage test with no significant bolt torque decay and no leakage at 300 psig.

The results of the residual flange bolt torque checks and helium leakage tests at 300 psig for Units F-1 through F-4 are contained in Figure 13. As can be seen in this figure, no particular torquing method indicated any significant improvement over the present acceptance test torque method. Therefore, no changes to the present torque method are recommended.

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IV. CONCLUSIONS

A. Apollo/LM configuration tank assemblies have demonstrated a useful operating life of one year.

B. If temperature cycling occurs over an extended period of time, a significant gas volume may form inside Apollo/LM configuration bladders.

C. Exposure to N_2O_4 , MMH and 50/50 fuel blend for one year has no adverse effect on Apollo/LM teflon bladder material.

D. Apollo/LM external tank flange seal configuration and the current production assembly method are adequate for a one-year shelf storage without degradation of seal integrity due to bolt torque decay.

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V. RECOMMENDATIONS

A. The effect of temperature cycling range and rate on gas bubble formation at various tank ullages should be determined.

B. The three tank assemblies that successfully completed the one year propellant storage should be placed back into storage for an additional year to more fully determine the actual mission life capability of this tank configuration.

C. The effect of shelf storage of up to five years on the external tank flange seal should be determined since it is anticipated that many missions will be flown using tanks delivered three to five years prior to launch.

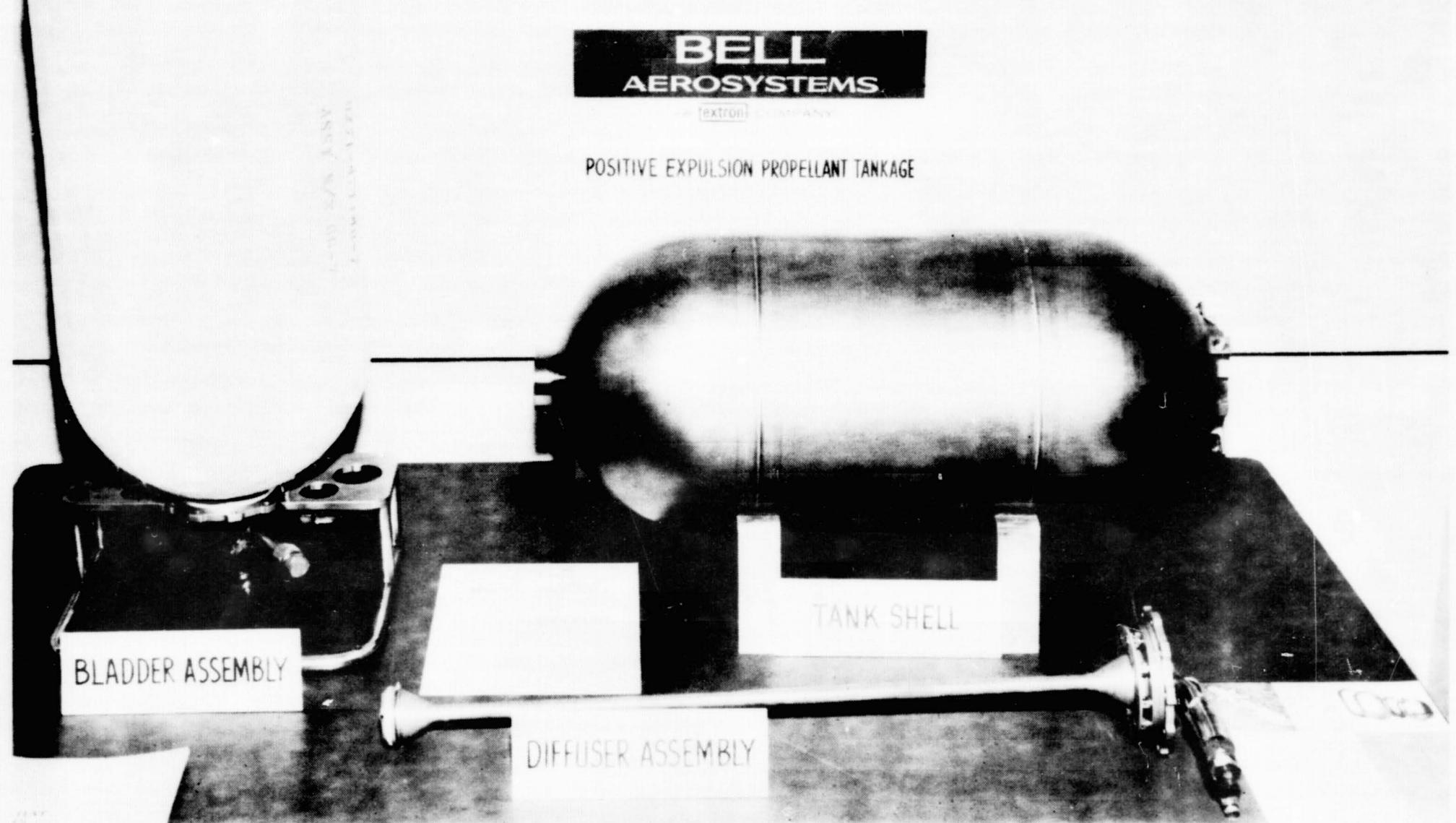


FIGURE 1. TYPICAL APOLLO RCS TANK

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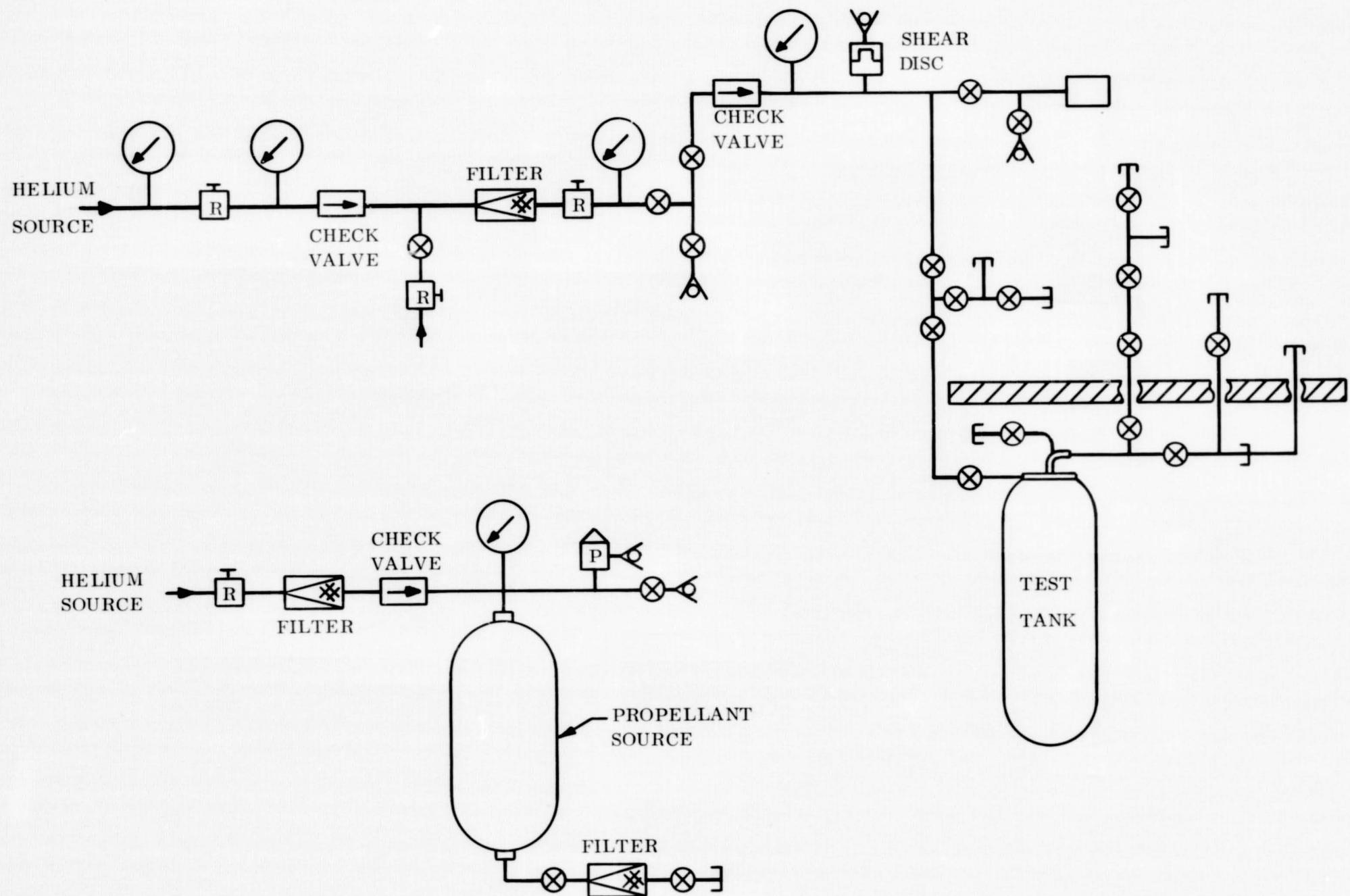


FIGURE 2. TANK ASSEMBLY STORAGE TEST - TYPICAL SCHEMATIC

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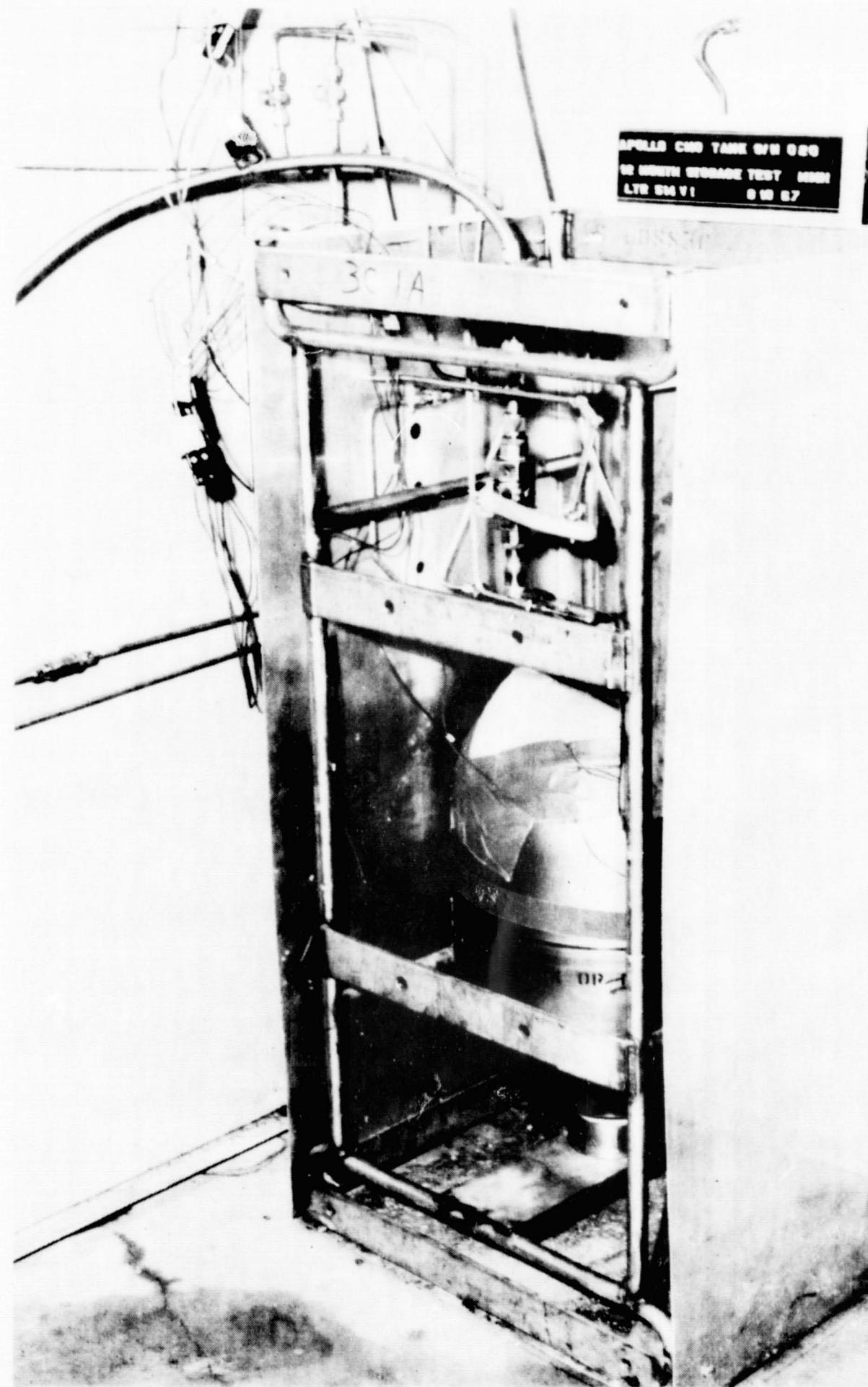


FIGURE 3. STORAGE TEST INSTALLATION

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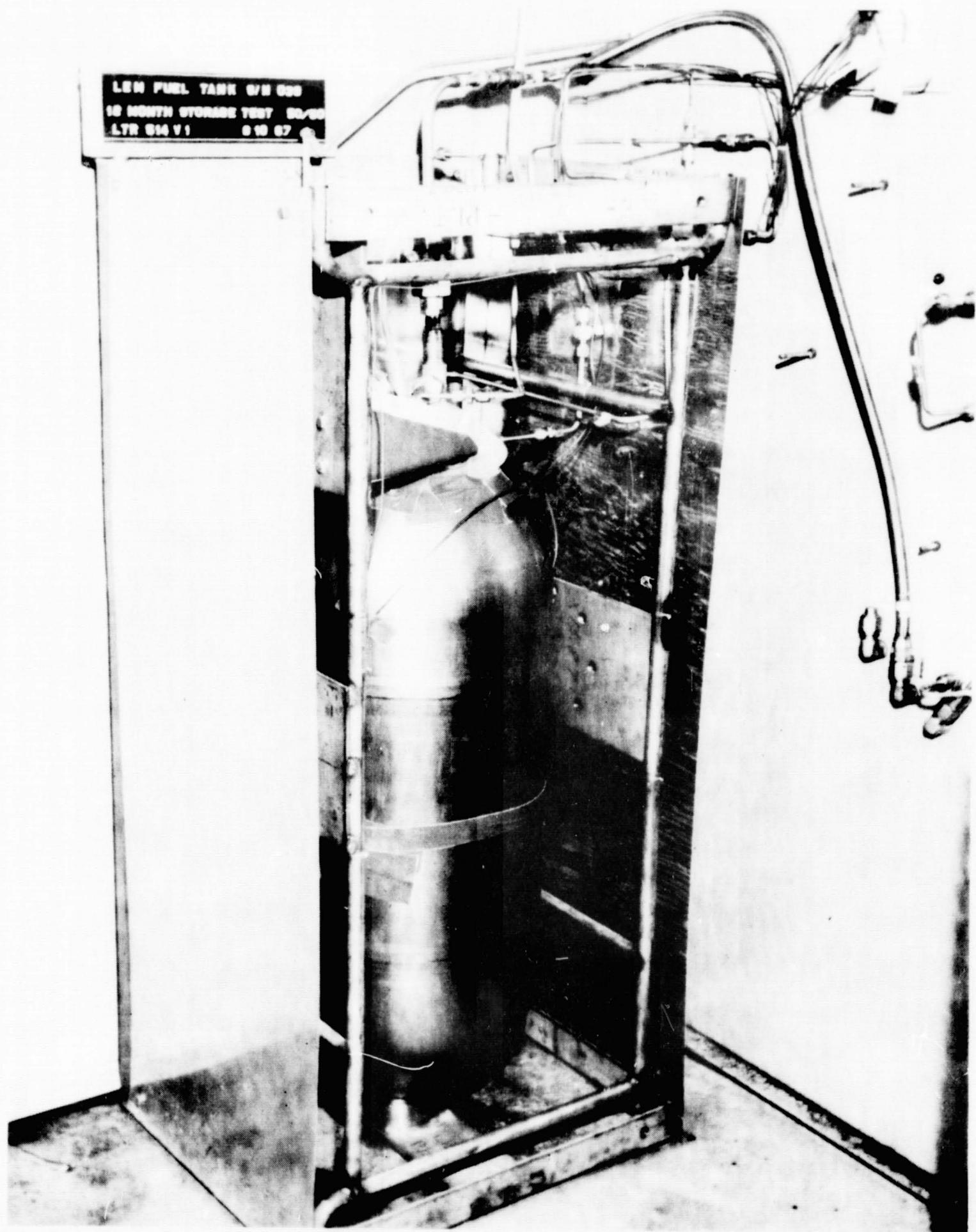


FIGURE 4. STORAGE TEST INSTALLATION

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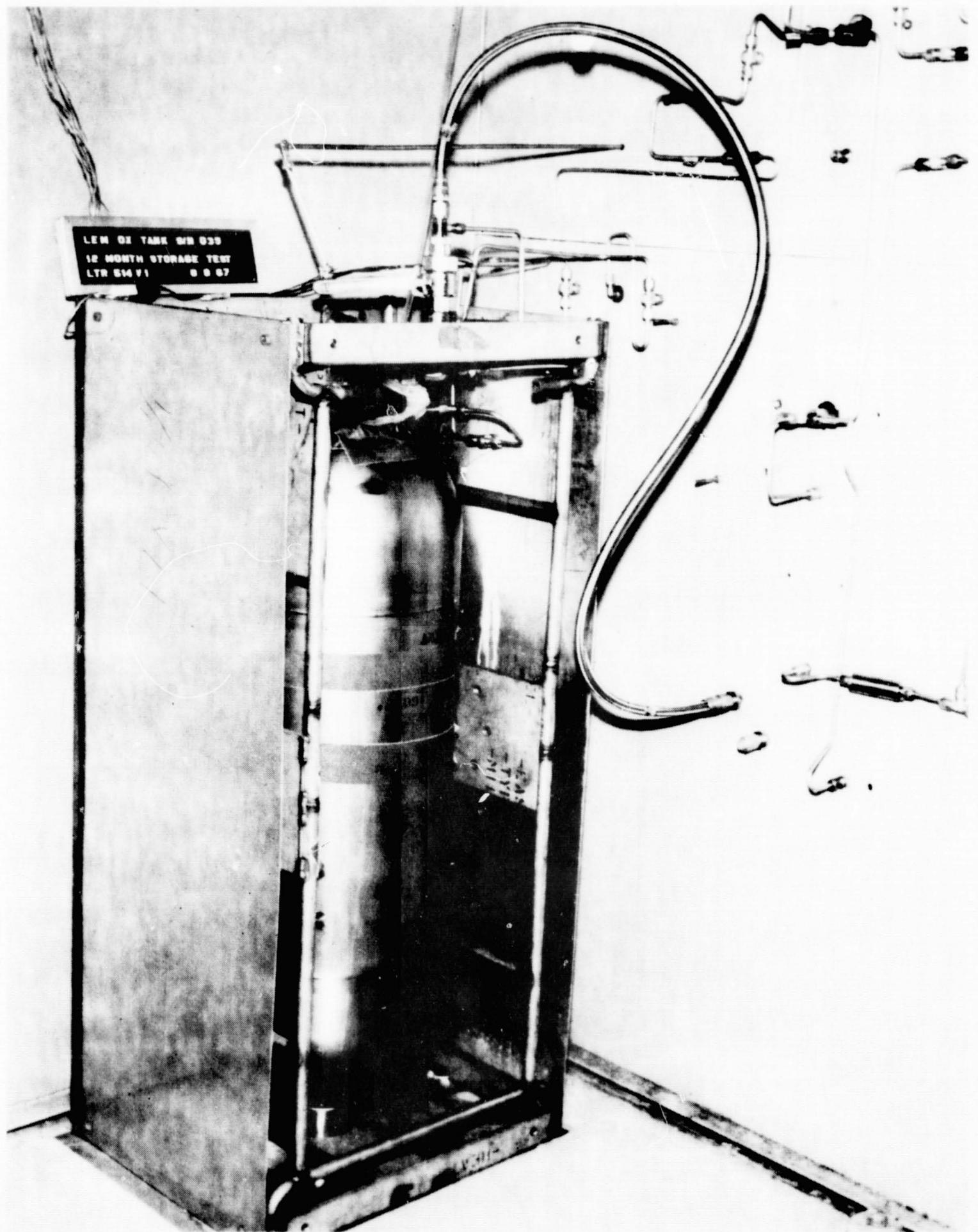


FIGURE 5. STORAGE TEST INSTALLATION

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NOTES:

1. MONTHLY RAISE T° TO 105°,
PRESSURE TO 250 PSIG
2. BURST DISC RUPTURE AND
PRESSURE DROP TO 24 PSIG

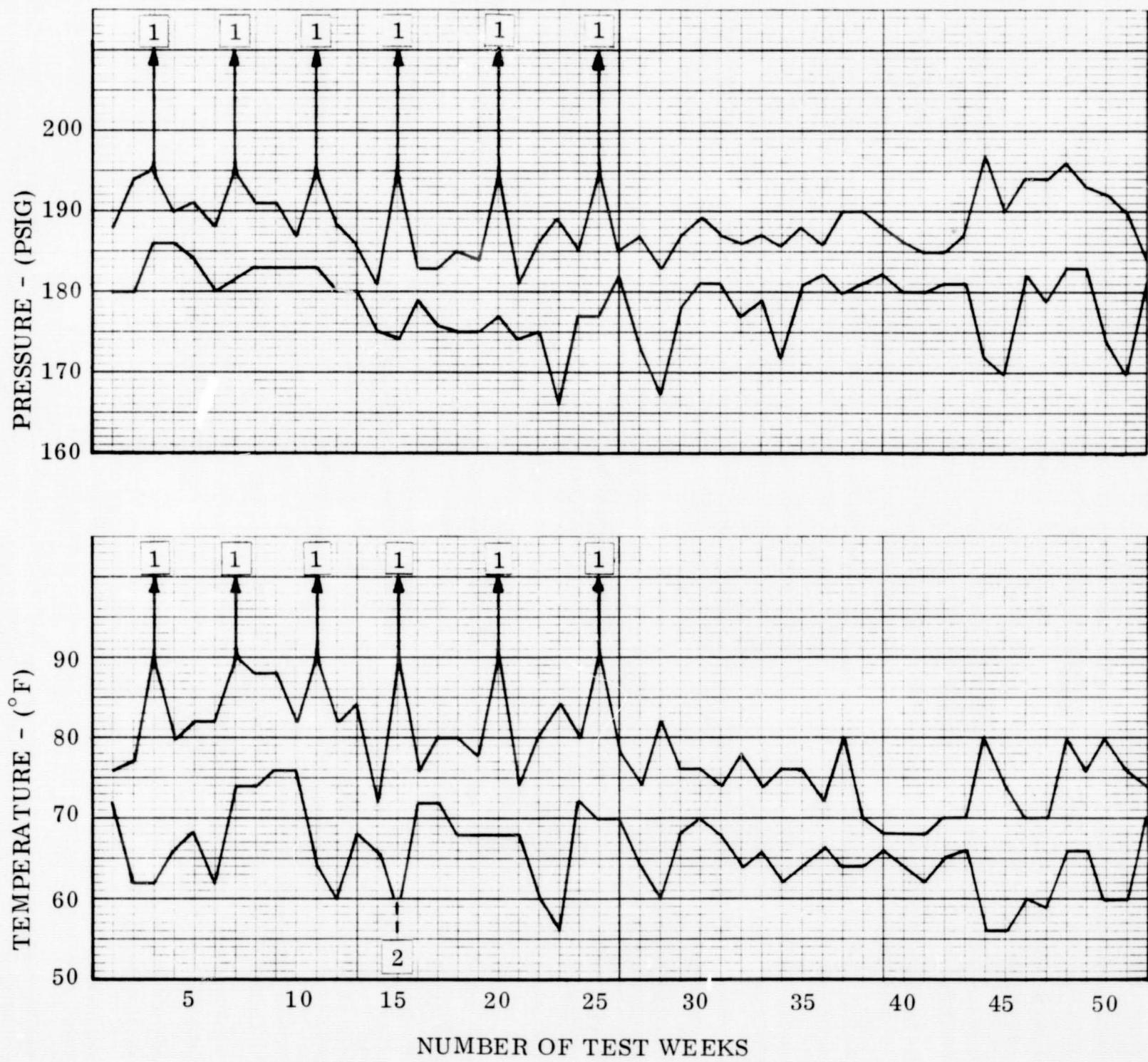


FIGURE 6. LMO SN-39 MINIMUM/MAXIMUM PRESSURE AND TEMPERATURE FOR EACH TEST WEEK

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NOTES:

1. MONTHLY - RAISE T° TO 105°,
PRESSURE TO 250 PSIG

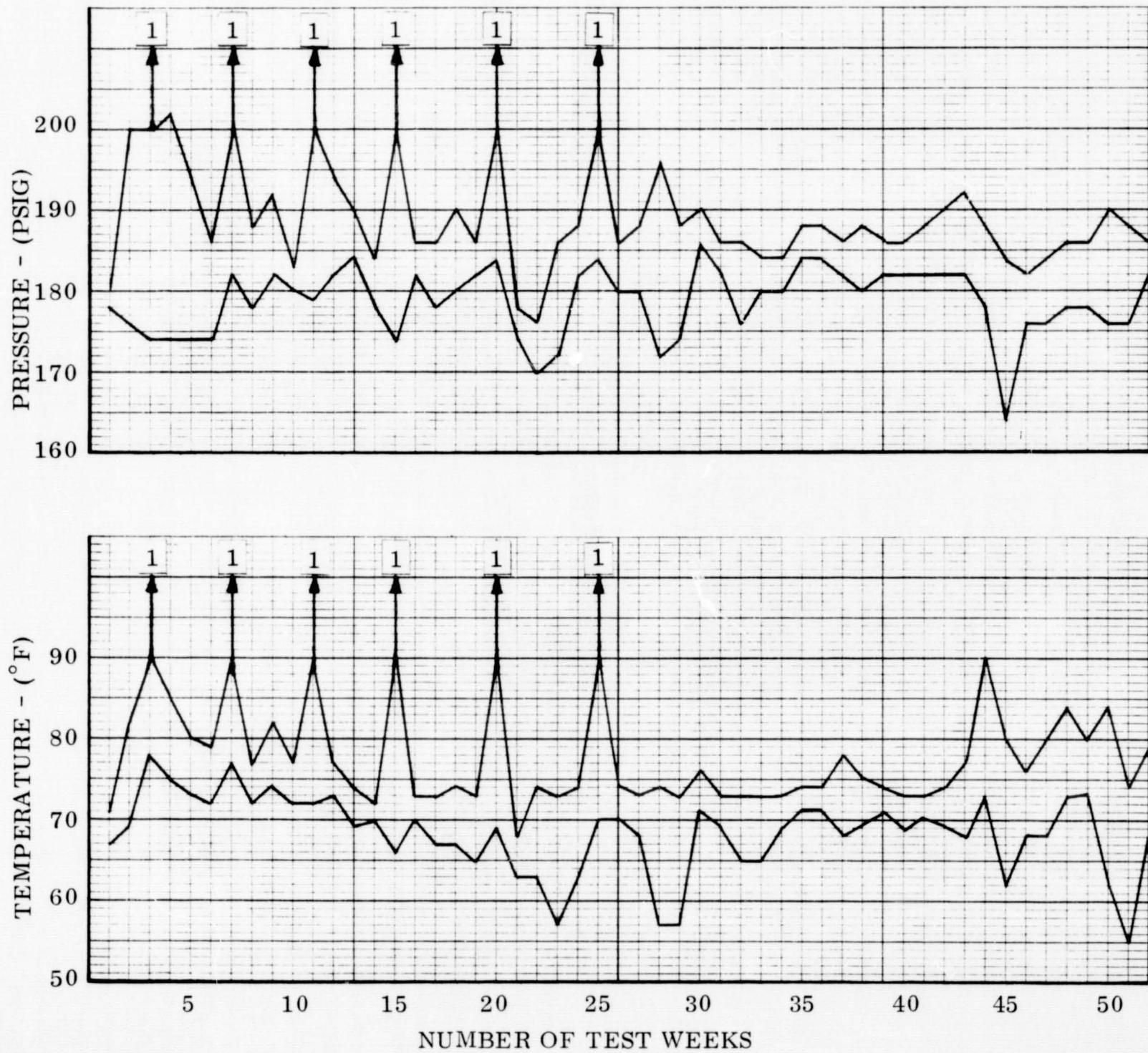


FIGURE 7. LMF SN-39 MINIMUM/MAXIMUM PRESSURE AND TEMPERATURE FOR EACH TEST WEEK

BELL AEROSYSTEMS COMPANY
DIVISION OF BELL AEROSPACE CORPORATION

NOTES:

1. BURST DISC LEAK - REPLACED
2. MONTHLY - RAISE T° TO 105°,
PRESSURE TO 360 PSIG

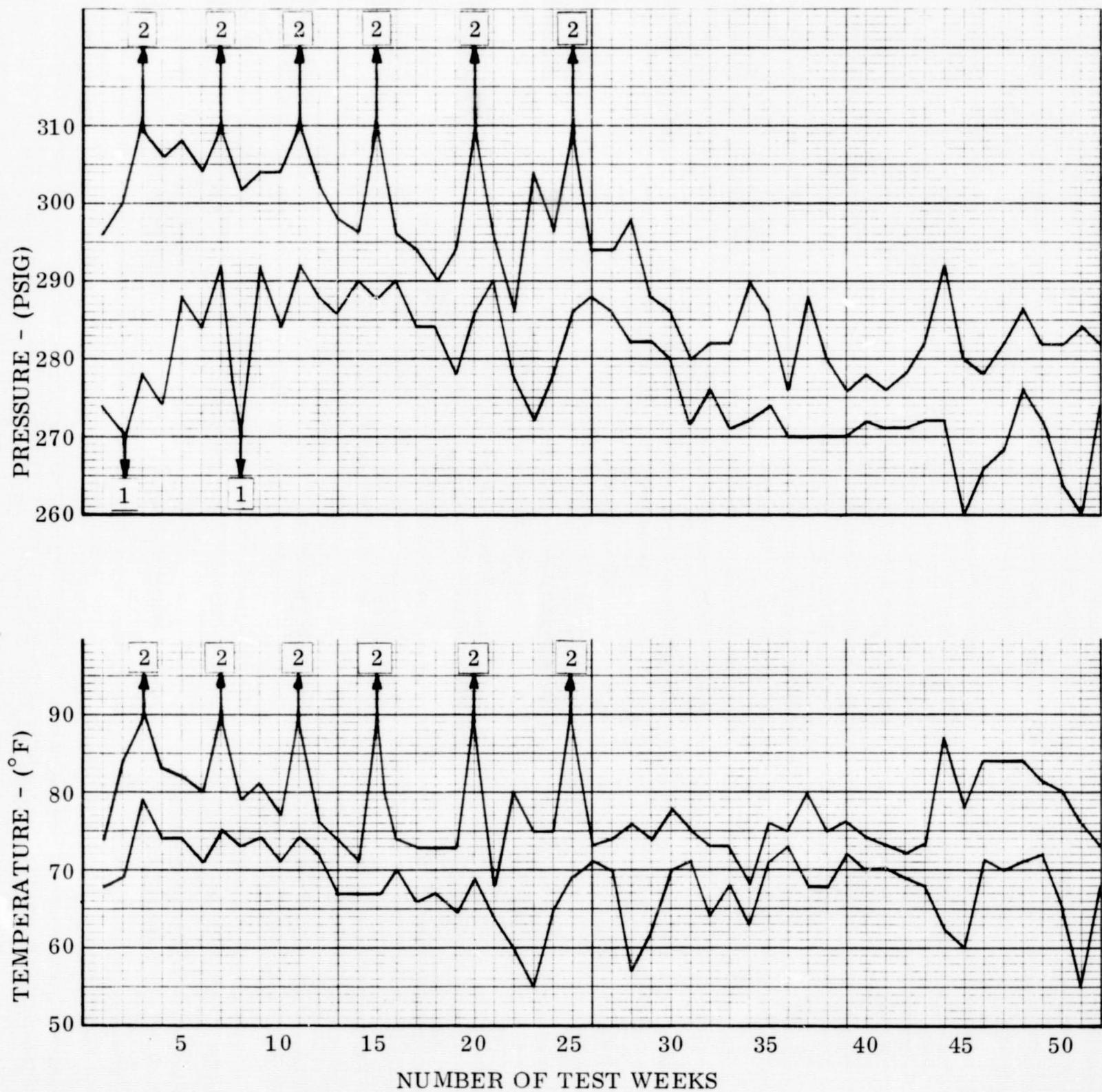


FIGURE 8. CMO SN-20 MINIMUM/MAXIMUM PRESSURE AND TEMPERATURE FOR EACH TEST WEEK

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FIGURE 9. POST STORAGE, INTERNAL VIEW OF CMO SN-20

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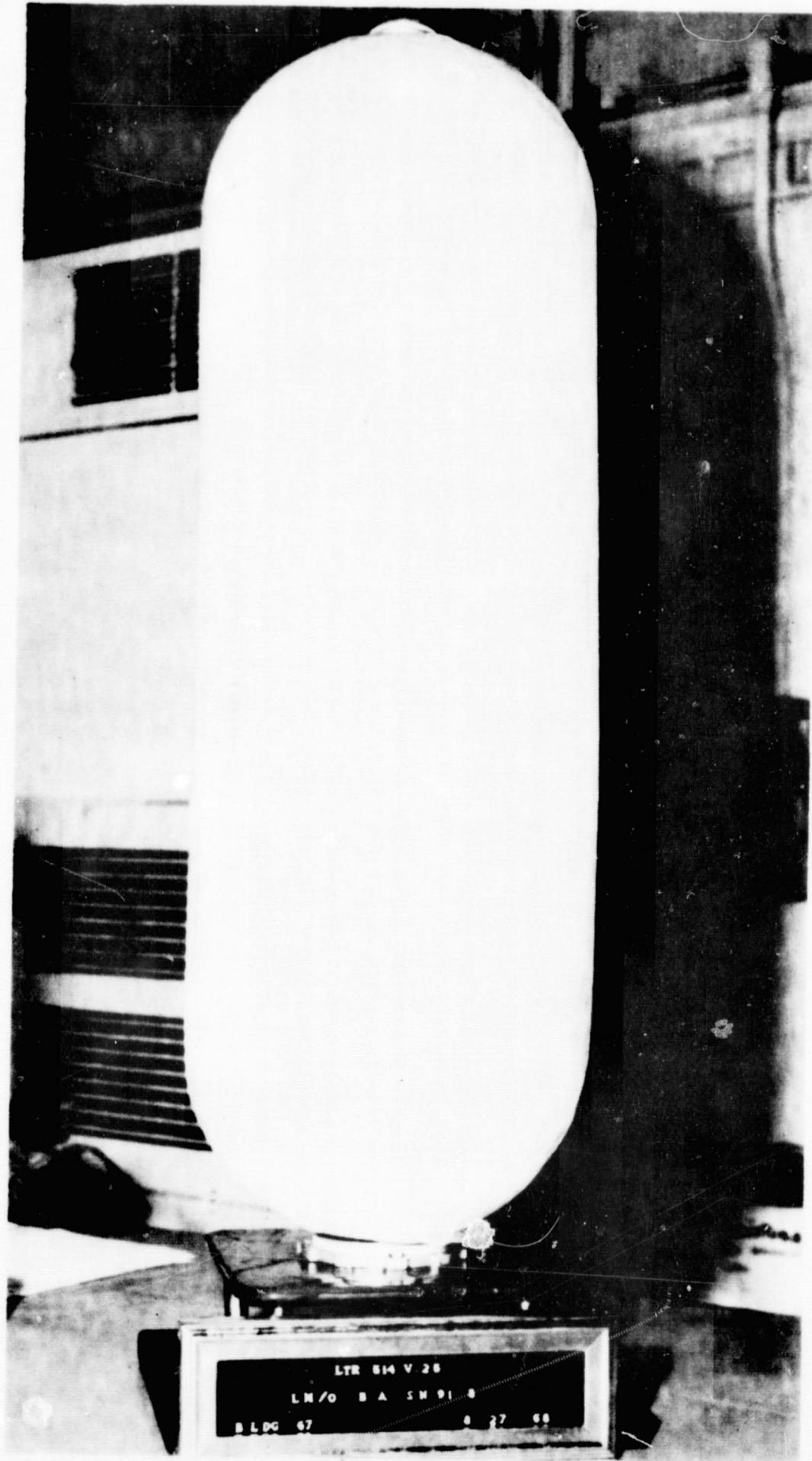


FIGURE 10. POST STORAGE VIEW OF LM OXIDIZER
BLADDER ASSEMBLY

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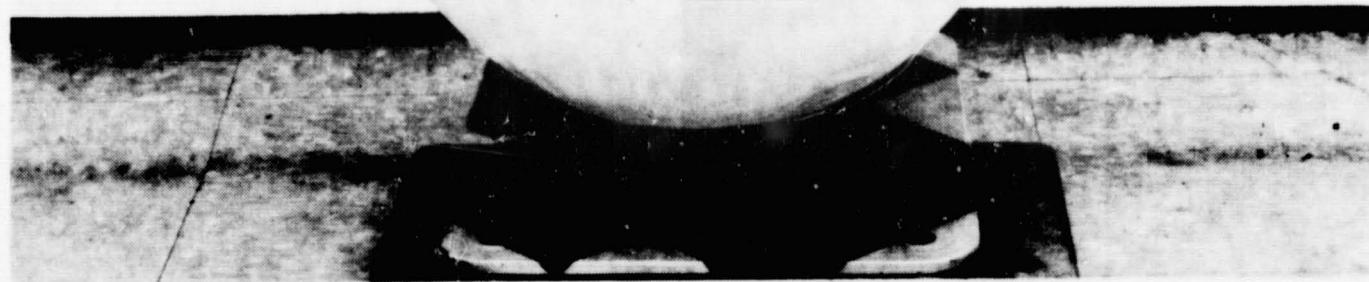


FIGURE 11. POST STORAGE TEST, LM FUEL BLADDER ASSEMBLY

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

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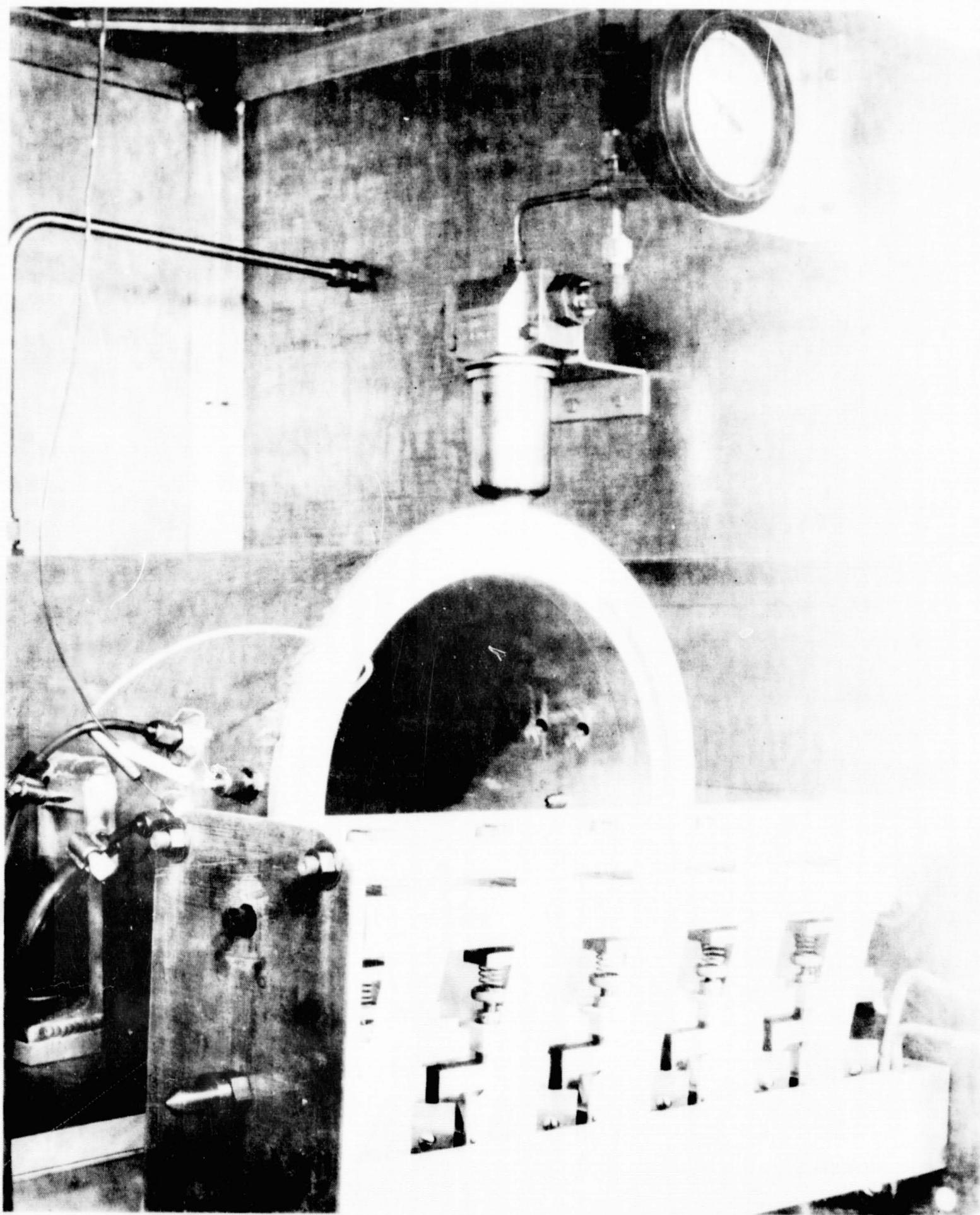


FIGURE 12. ROLLING OF BUCKLED FOLD TEST MACHINE

△ - FLANGE LEAKAGE TESTS, ZERO LEAKAGE AT
360 PSIG HELIUM

TEST DATES: 9 - 67 TO 10 - 68

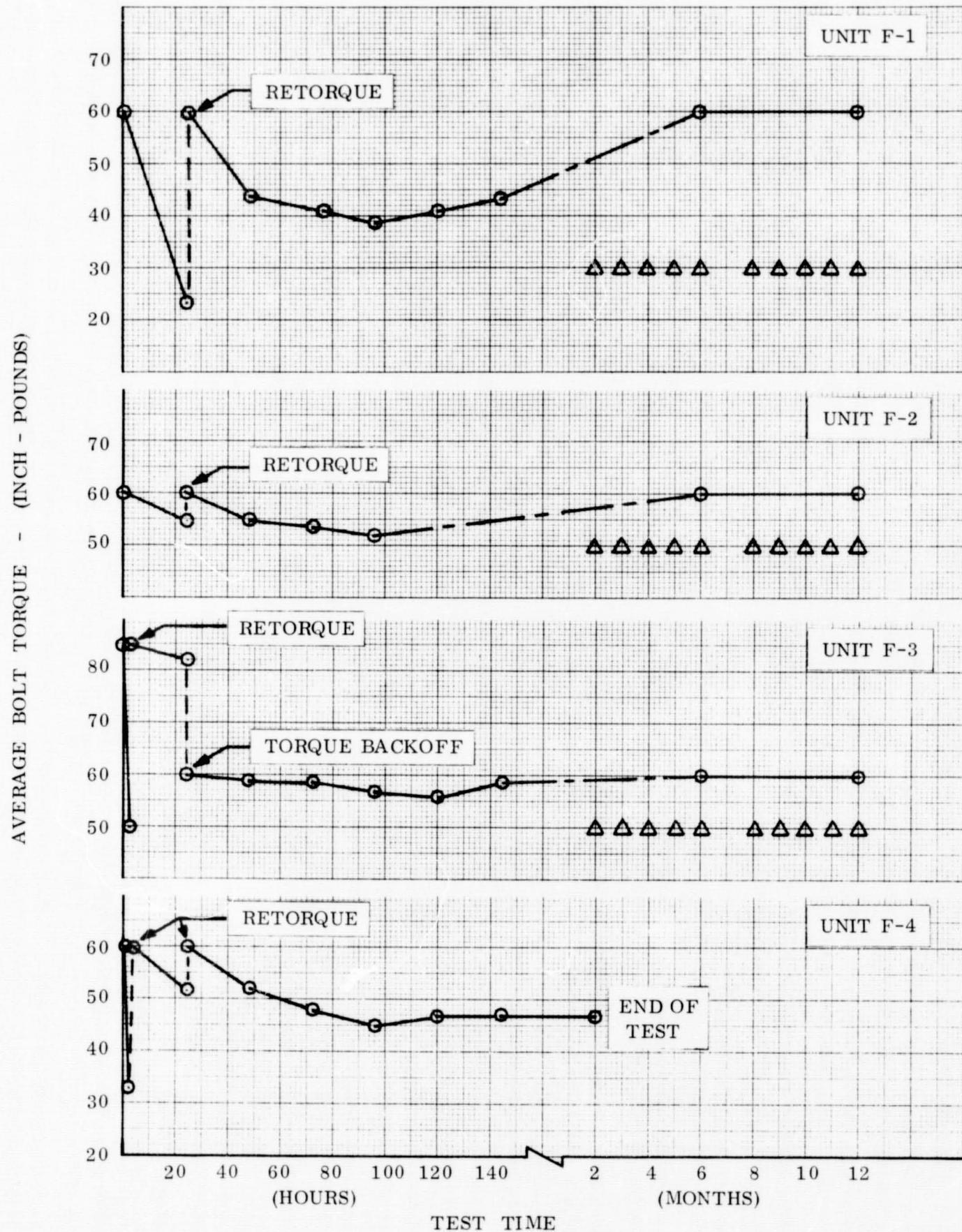


FIGURE 13. EXTERNAL FLANGE SEAL EVALUATION

TABLE 1
ONE YEAR TANK STORAGE PROGRAM HARDWARE

ITEM	LUNAR MODULE OXIDIZER (LMO)	LUNAR MODULE FUEL (LMF)	APOLLO COMMAND MODULE OXIDIZER (CMO)
TANK ASSEMBLY P/N	8339-471102-7	8339-471101-7	8271-471154-1
TANK ASSEMBLY S/N	39	39	20
BLADDER P/N	8339-471080-3	8339-471080-1	8271-471160-1
BLADDER S/N	91-3	52-1	113-1
DIFFUSER ASSEMBLY P/N	8339-471054-3	8339-471053-3	8271-471200-3
DIFFUSER ASSEMBLY S/N	50	57	234
LOADABLE VOLUME (IN. ³)	4100	3303	1783
DIAMETER (IN.)	12.5	12.5	12.5
LENGTH (IN.)	38.8	32.2	19.9
OPERATING PRESSURE (PSIG)	181	181	289
MAX OPERATING PRESSURE (PSIG)	250	250	360

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TABLE 2

ONE YEAR TANK STORAGE ACCEPTANCE TEST RESULTS

TEST	LMO		LMF		CMO	
	ORIGINAL A/T	PRESTORAGE A/T	ORIGINAL A/T	PRESTORAGE A/T	ORIGINAL A/T	PRESTORAGE A/T
VISUAL INSPECTION	NO DAMAGE	NO DAMAGE	NO DAMAGE	NO DAMAGE	NO DAMAGE	NO DAMAGE
BLADDER LEAKAGE SCC/15 MIN HELIUM AT 10 PSI	97	93	62	70	50	52
FLANGE LEAKAGE HELIUM	250 PSIG - NONE	250 PSIG - NONE	250 PSIG - NONE	250 PSIG - NONE	360 PSIG - NONE	360 PSIG NONE
FLANGE TORQUE (RESIDUAL) (IN/LB)	TORQUE 60	30 - 40 RETORQUED TO 60	TORQUE 60	40 - 52 RETORQUED TO 60	TORQUE 60	35 - 50 RETORQUED TO 60
CLEANLINESS LEVEL	IN SPEC.	IN SPEC.	IN SPEC.	IN SPEC.	IN SPEC.	IN SPEC.

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TABLE 3
ONE YEAR TANK STORAGE PROGRAM EXPULSION SCHEDULE

EXPULSION NO.	LMO - N ₂ O ₄			LMF - 50/50			CMO - MMH		
	TEST DAYS	WEIGHT IN TANK (LB)	% FULL	TEST DAYS	WEIGHT IN TANK (LB)	% FULL	TEST DAYS	WEIGHT IN TANK (LB)	% FULL
Full	0	214.1	100	0	106.7	100	0	56.1	100
Post-Ullage	0	203.8	95	0	103.5	97	0	54.1	96.5
1	26	203.3	94.7	21	102.8	96.3	21	53.4	96.3
2	53	190.6	89	51	97.0	91	51	51.1	91
3	84	178.0	83	82	90.6	85	82	47.7	85
4	114	165.0	77	112	84.3	79	112	44.3	79
5	145	154.1	72	143	79.0	74	143	41.0	73
6	176	141.4	66	174	72.6	68	174	37.6	67
7	205	128.5	60	203	65.1	61	203	33.1	59
8	378	EXPELLED REMAINDER		373	EXPELLED REMAINDER		370	EXPELLED REMAINDER	

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TABLE 4
ONE YEAR TANK STORAGE PROGRAM PROPELLANT ANALYSES RESULTS (% WEIGHT)

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TEST DAY	LMO - N ₂ O ₄						CMO - MMH				LMF - 50/50				
	SPECIFIC GRAVITY	% N ₂ O ₄	% N _O	% H ₂ O	% FE	% H _E	SPECIFIC GRAVITY	% MMH	% IMPURITIES	% H _E	SPECIFIC GRAVITY	% UDMH	% N ₂ H ₂	% IMPURITIES	% H _E
0	1.458	99.51	0.58	0.10	1PPM	NIL	.879	99.23	0.8	NIL	.908	48.0	51.3	0.7	NIL
12	-	-	-	-	-	7x10 ⁻³	-	-	-	4.5x10 ⁻³	-	-	-	-	1.7x10 ⁻³
19	-	-	-	-	-	1.4x10 ⁻³	-	-	-	1.8x10 ⁻³	-	-	-	-	4.0x10 ⁻⁴
25	-	-	-	-	-	-	-	-	-	2.5x10 ⁻²	-	-	-	-	5.2x10 ⁻³
34	-	-	-	-	-	1.3x10 ⁻³	-	-	-	2.1x10 ⁻³	-	-	-	-	1.7x10 ⁻³
65	-	-	-	-	-	8x10 ⁻⁴	-	-	-	5.0x10 ⁻³	-	-	-	-	4.4x10 ⁻³
89	-	-	-	-	-	1.4x10 ⁻³	-	-	-	2.8x10 ⁻³	-	-	-	-	-
120	-	-	-	-	-	1.0x10 ⁻³	-	-	-	4.0x10 ⁻³	-	-	-	-	2.1x10 ⁻⁴
156	-	-	-	-	-	1.6x10 ⁻³	-	-	-	8.3x10 ⁻³	-	-	-	-	2.9x10 ⁻³
185	-	-	-	-	-	1.8x10 ⁻³	-	-	-	2.0x10 ⁻³	-	-	-	-	2.0x10 ⁻³
370	1.457	98.96	0.49	0.05	1PPM	2.4x10 ⁻³	.880	98.71	1.3	2.3x10 ⁻³	.909	47.7	51.2	1.1	2.3x10 ⁻³
SPEC.	1.457 ± .002	≥ 98.7	.4-	≤ .10	-	-	.881 ± .002	≥ 98.0	≤ 2.0	-	.908 ± .002	≥ 47.1	≥ 51.0	≤ 2.0	-

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TABLE 5
ONE YEAR TANK STORAGE PROGRAM
PRESSURANT GAS ANALYSES RESULTS (% VOLUME)

TEST DAY	LMO - N ₂ O ₄				CMO - MMH				LMF - 50/50			
	% N ₂ O ₄	% NO ₂	% NO	% He	% MMH	% CH ₄	% NH ₃	% He	% 50/50	% CH ₄	% NH ₃	% He
0	0	0	0	100	0	0	0	100	0	0	0	100
12	4.2	2.2	<0.1	93.6	0	.05	0	99.95	0	0	0	100
19	3.7	2.0	<0.1	94.6	0	.08	0	99.92	0	0	0	100
25	3.5	2.0	<0.1	94.5	0	0	0	100	0	0	0	100
34	4.7	2.3	<0.1	93.0	0	.10	0	99.90	0	0	0	100
65	4.6	2.3	<0.1	93.1	0	.13	0	99.87	0	0	0	100
89	3.5	2.0	<0.1	94.5	0	.10	0	99.90	0	-	<.10	> 99.9
120	4.1	2.2	<0.1	93.7	0	-	<.10	-	0	0	0	100
156	4.9	2.1	<0.1	92.7	0	-	<.10	-	-	-	<.10	100
185	4.8	2.3	<0.1	92.9	0	-	<.10	-	0	0	0	100
370	4.8	2.3	<0.1	92.8	0	<.10	<.10	>99.9	0	2.7	1.15	96.1

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TABLE 6
ONE YEAR TANK STORAGE PROGRAM GAS BUBBLE FORMATION

DATE	LMO - N ₂ O ₄	LMF - 50/50	CMO - MMH
2-12-68	ZERO GAS	ZERO GAS	ZERO GAS
3-20-68	GAS IN OUTLET	1 IN. LIQUID LEVEL*	ZERO GAS
4-15-68	13 IN. LIQUID LEVEL*	6 IN. LIQUID LEVEL	GAS IN OUTLET
5-15-68	17 IN. LIQUID LEVEL	13 IN. LIQUID LEVEL	GAS IN OUTLET
6-17-68	17 IN. LIQUID LEVEL	14 IN. LIQUID LEVEL	GAS IN OUTLET
7-19-68	18 IN. LIQUID LEVEL**	14 IN. LIQUID LEVEL	GAS IN OUTLET
8-7-68	18 IN. LIQUID LEVEL	16 IN. LIQUID LEVEL**	GAS IN OUTLET
GAS BUBBLE VOLUME BLED	812 CC @ 174 PSIG	3358 CC @ 180 PSIG	60 CC @ 274 PSIG

- * LIQUID LEVEL IS THE DISTANCE BETWEEN THE LEVEL OF PROPELLANT IN THE DIFFUSER TUBE AND THE TANK FLANGE
- ** LIQUID LEVEL IN DUFFUSER WAS EVEN WITH MEAN LIQUID LEVEL IN TANK

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TABLE 7
ONE YEAR TANK STORAGE PROGRAM BLADDER LEAKAGE RATES

TEST	LEAKAGE RATE *		
	LMO	LMF	CMO
ORIGINAL ACCEPTANCE TEST	97	62	50
PRESTORAGE ACCEPTANCE TEST	93	70	52
POSTSTORAGE	123	53	47
MAXIMUM ALLOWABLE (NEW)	143	120	65

* SCC HELIUM/15 MINUTES AT P = 10 PSI

TABLE 8

BLADDERS USED IN LONG TERM MATERIAL COMPATIBILITY TEST PROGRAM

BLADDER S/N	NUMBER OF N ₂ O ₄ SPECIMENS						NUMBER OF MMH SPECIMENS						NUMBER OF 50/50 SPECIMENS						TOTAL	
	24 HOUR		180 DAY		365 DAY		24 HOUR		180 DAY		365 DAY		24 HOUR		180 DAY		365 DAY			
	35°	75°	35°	75°	35°	75°	35°	75°	35°	75°	35°	75°	35°	75°	35°	75°	35°	75°		
25-1	0	0	7	6	8	2	0	0	0	0	0	0	0	0	0	0	0	0	23	
32-1	0	0	0	0	0	0	0	0	0	0	3	4	0	0	0	0	6	5	18	
41-1	0	0	0	0	0	0	0	9	0	0	2	5	0	4	0	0	6	6	32	
34-3	0	8	7	6	7	3	0	0	0	0	0	0	0	0	0	0	0	0	31	
35-3	0	0	0	0	4	5	0	0	4	8	5	8	0	0	0	0	0	0	34	
47-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	6	3	9	23	
53-3	0	7	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	17	
56-3	12	0	0	0	0	0	9	0	0	0	0	0	10	4	0	0	0	0	35	
61-3	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	10	
62-3	0	0	0	0	1	10	0	0	0	0	0	0	0	0	3	9	5	5	33	
63-3	0	0	0	0	0	0	0	9	5	6	10	3	0	3	0	0	0	0	36	
69-3	9	0	0	0	0	0	9	0	0	0	0	0	0	4	0	0	0	0	22	
87-3	0	0	5	7	0	0	0	1	5	7	0	0	0	0	6	5	0	0	36	
93-3	14	0	0	0	0	0	7	6	0	0	0	0	0	15	0	0	0	0	42	
102-3	0	0	6	6	0	0	0	0	6	4	0	0	0	0	6	5	0	0	33	
TOTAL	35	15	25	25	20	20	25	35	20	25	20	20	20	30	20	25	20	25	425	

BLADDER P/N = 8339-471080-1 FOR S/N 25-1 THROUGH 41-1

8339-471080-3 FOR S/N 34-3 THROUGH 102-3

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TABLE 9
 RESULTS OF ROLLING OF BUCKLED FOLD
 CYCLE LIFE TESTS AFTER PROPELLANT STORAGE

PROPELLANT	NUMBER OF SPECIMENS	STORAGE TIME (DAYS)	TEST TEMPERATURE (°F)	CYCLE LIFE TO FAILURE
N_2O_4	35	1	35	2000 TO >25,000
	25	180		1000 TO >40,000
	20	365		25,000 TO >50,000
	15	1	75	> 25,000
	25	180		> 40,000
	20	365		> 50,000
MMH	25	1	35	100 TO 300
	20	180		100 TO 300
	20	365		50 TO >200
	35	1	75	1000 TO 15,000
	25	180		3000 TO >15,000
	20	365		5000 TO >15,000
50/50 FUEL	20	1	35	100 TO 500
	20	180		100 TO 300
	20	365		50 TO 200
	45	1	75	1000 TO >25,000
	25	180		1000 TO 25,000
	25	365		1000 TO >25,000

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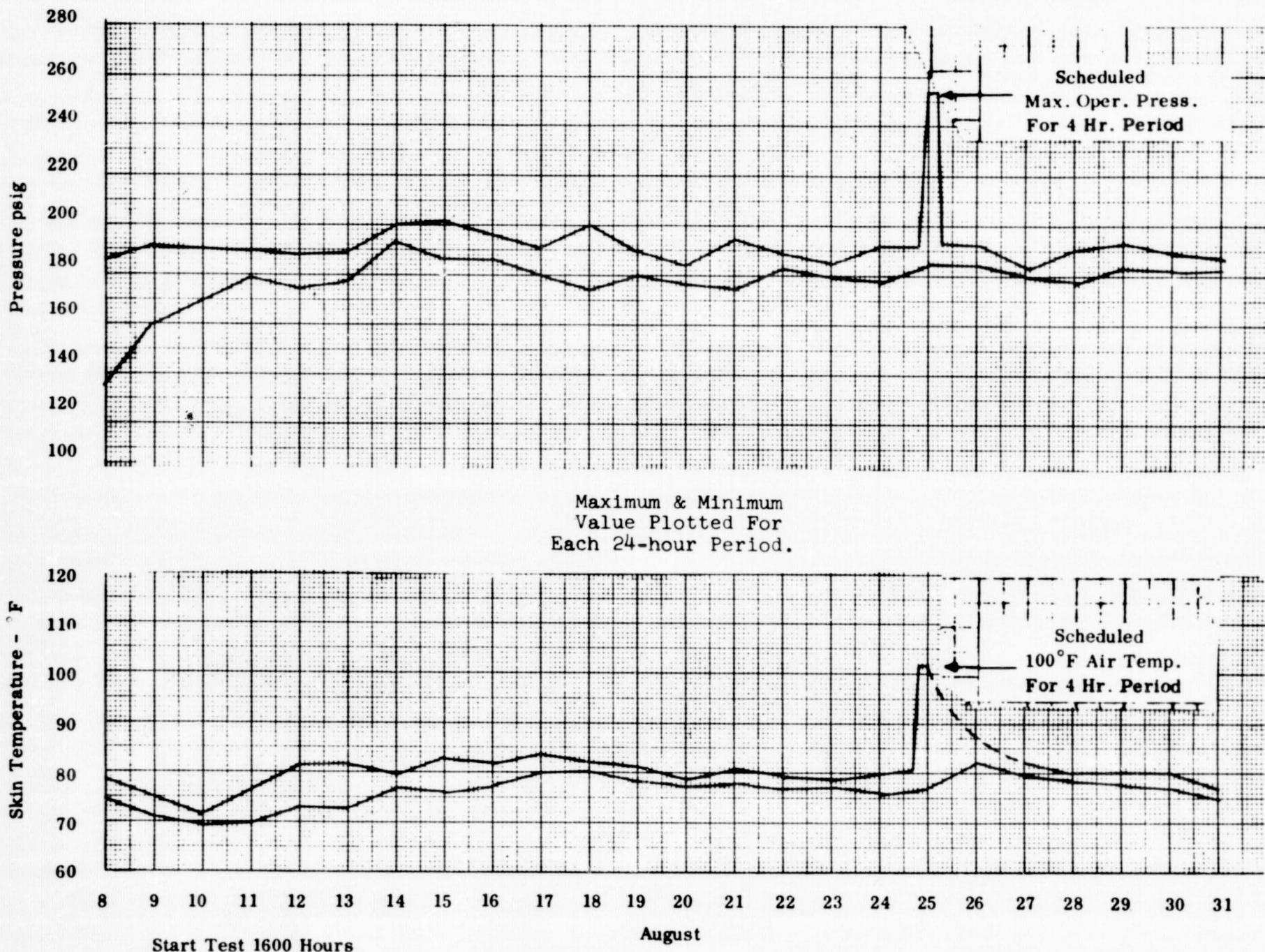
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APPENDIX I

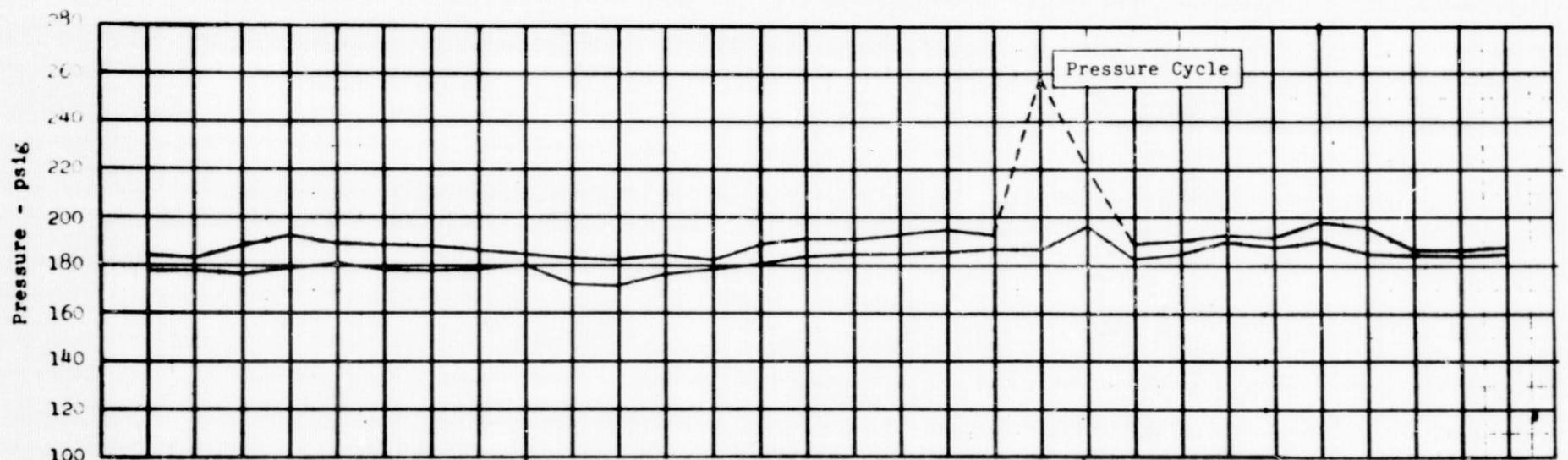
LMO SN 39 ONE YEAR STORAGE
MINIMUM AND MAXIMUM PRESSURE
AND TEMPERATURE EACH DAY

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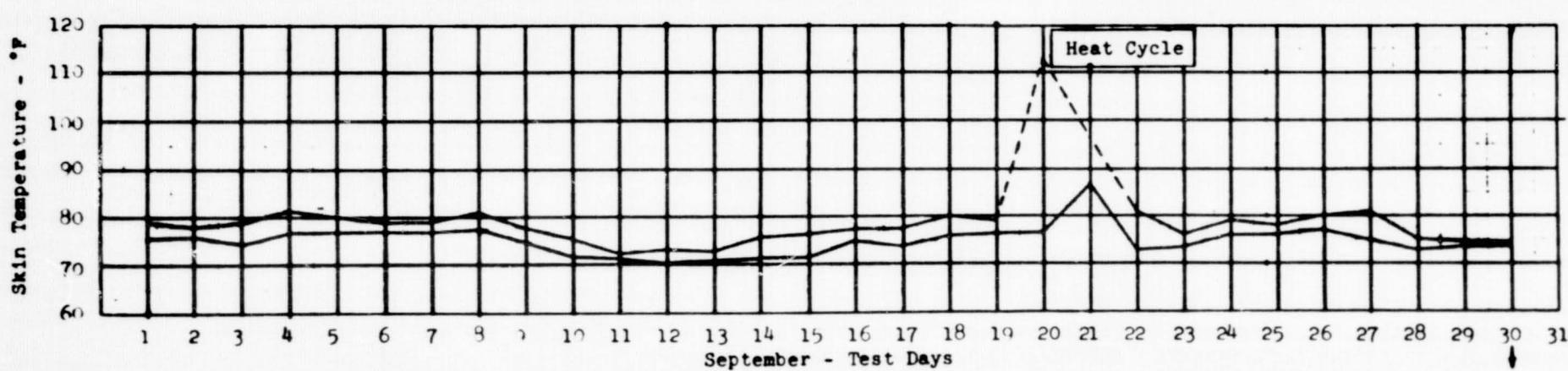
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LM OXIDIZER TANK SN 039, ONE YEAR STORAGE TEST - N₂O₄

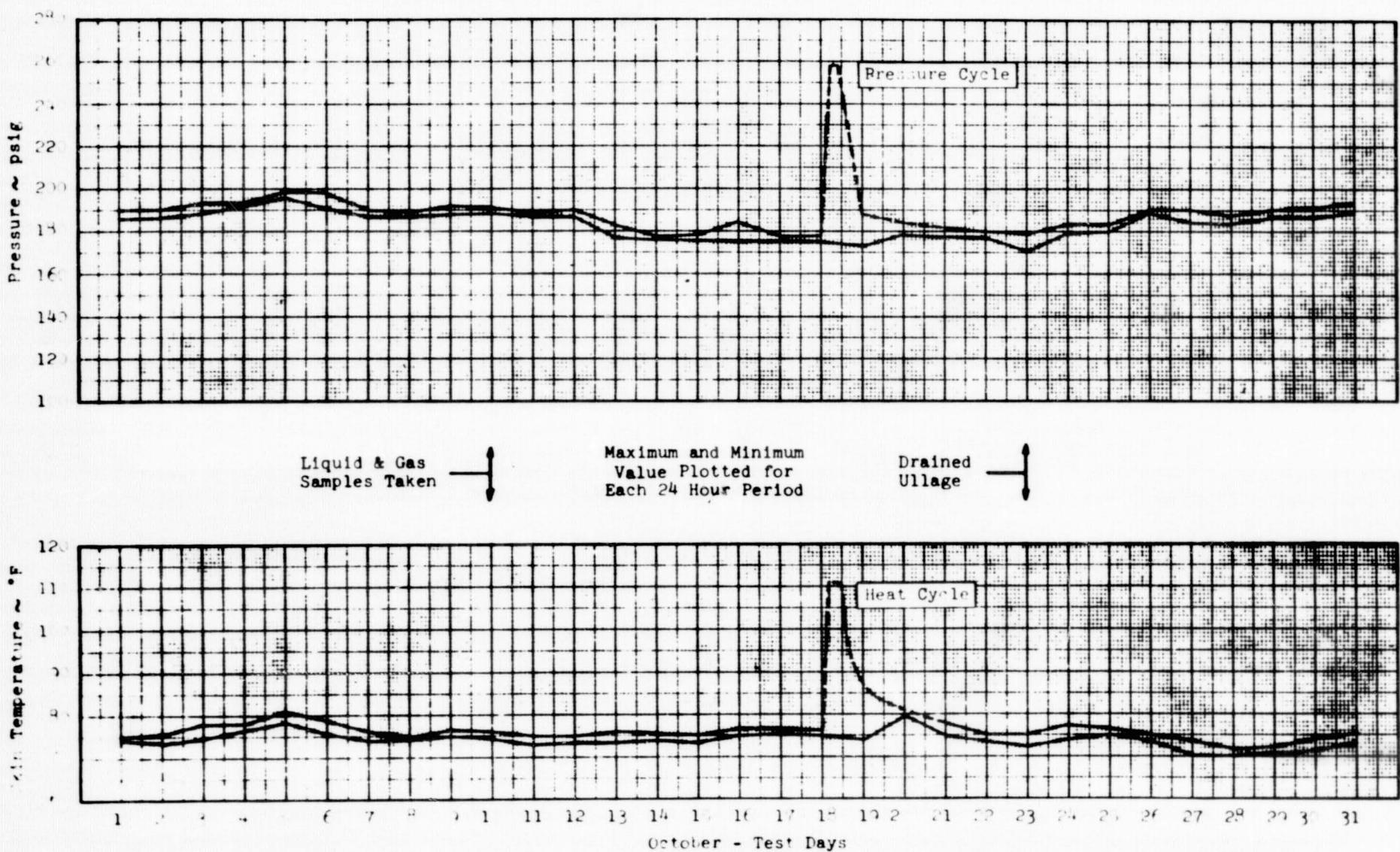


Maximum and Minimum
Value Plotted for Each
24 Hour Period



LM OXIDIZER TANK SN 039, ONE YEAR STORAGE TEST - N₂O₄

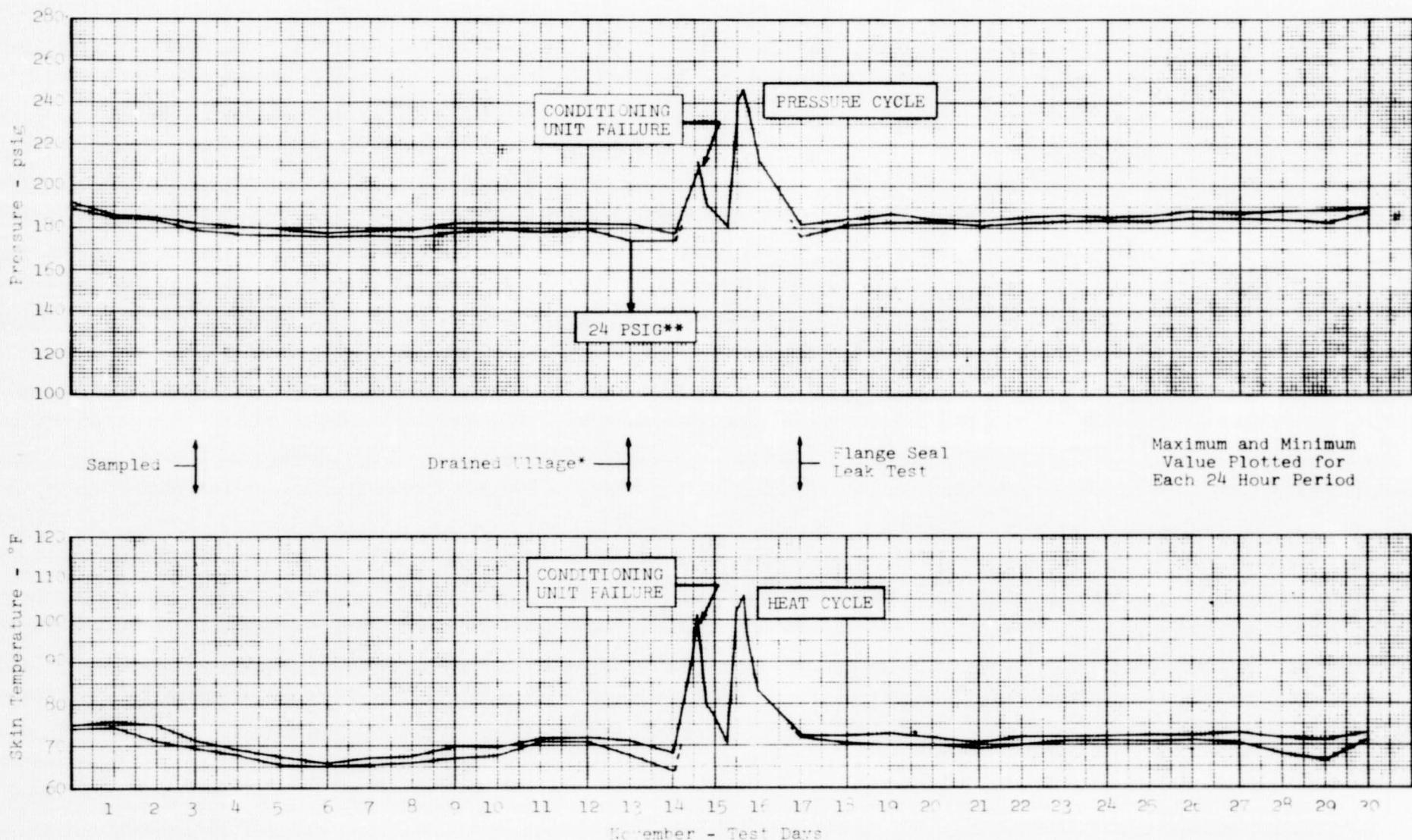
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LM OXIDIZER TANK SN 039, ONE YEAR STORAGE TEST - N₂O₄

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* - Pressure Dropped to 12 psig During Ullage Draining

** - Disc Ruptured - Pressure Dropped to 24 psig

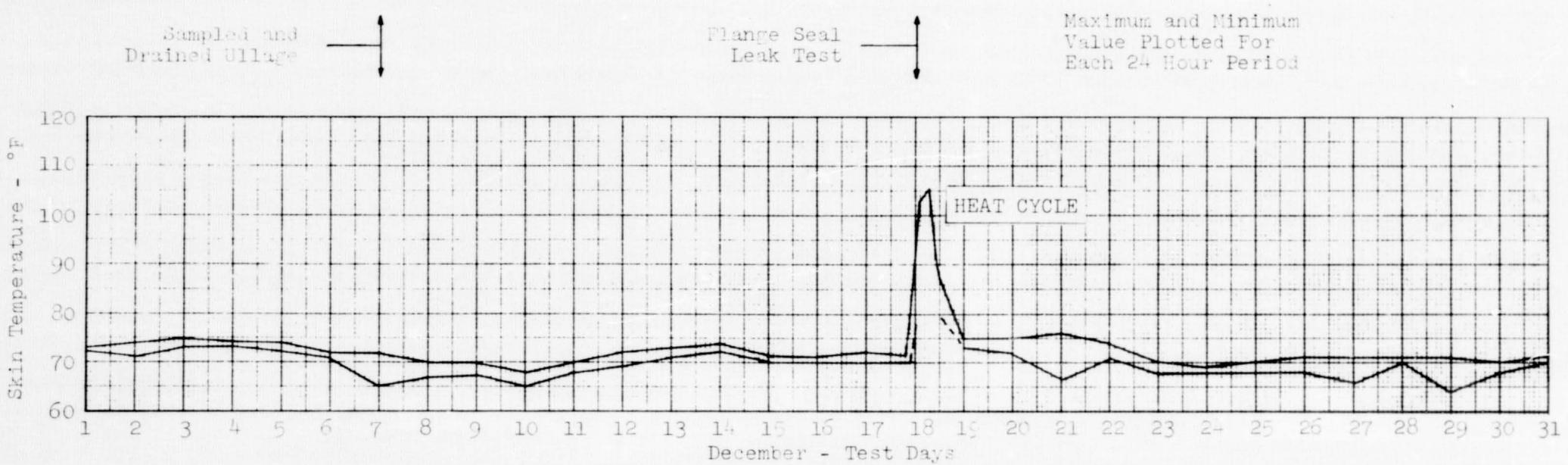
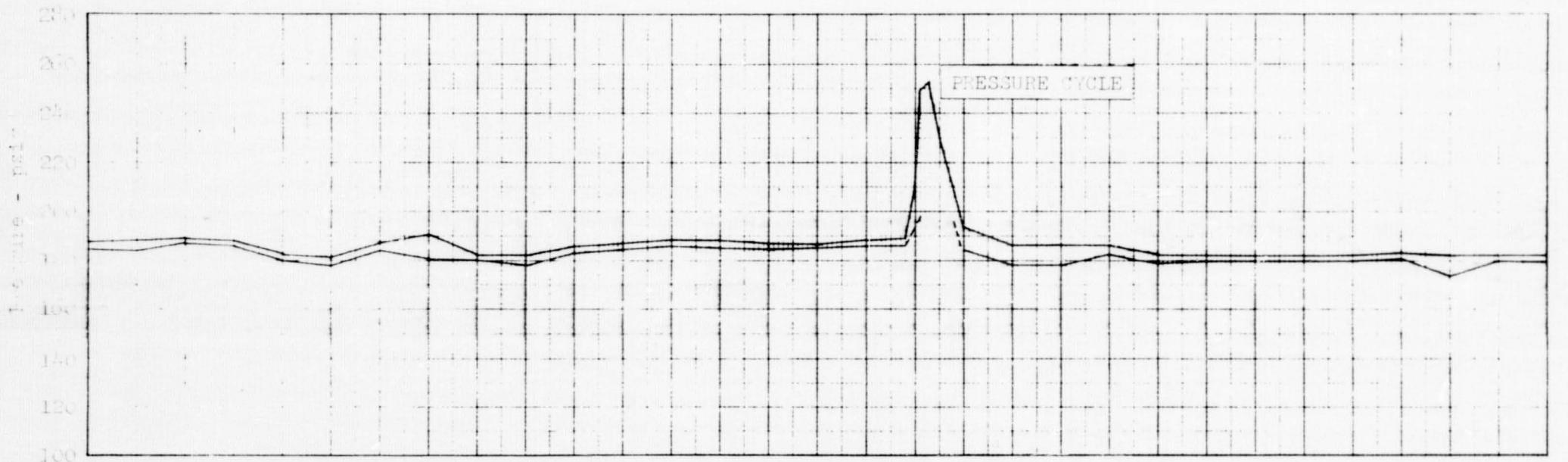
LM OXIDIZER TANK SN 039
 ONE YEAR STORAGE TEST - N₂O₄

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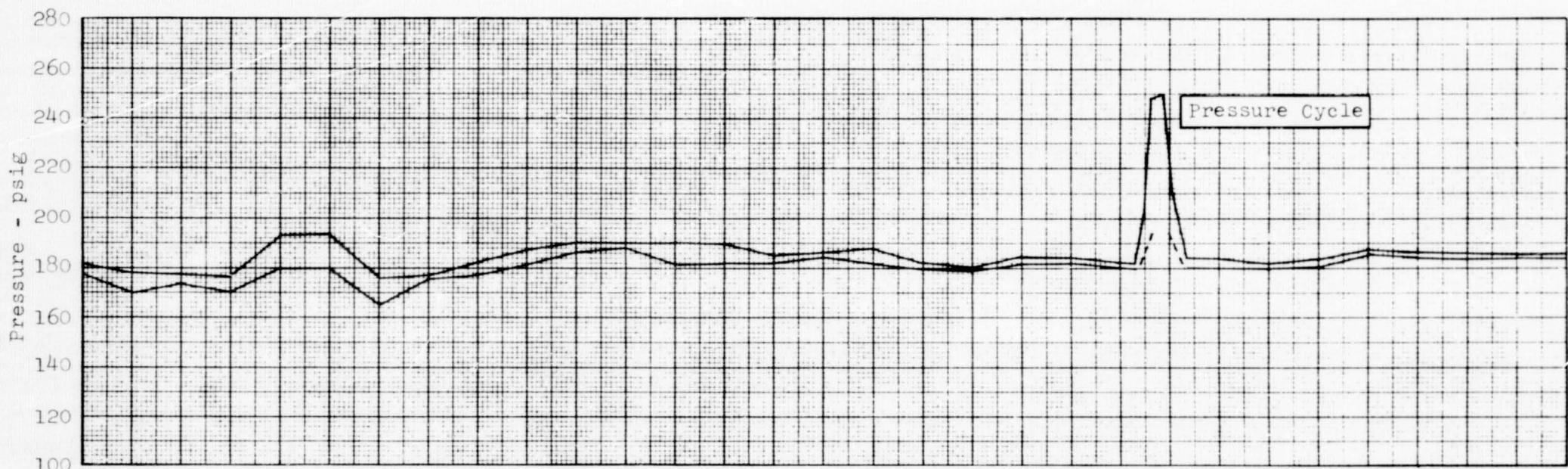
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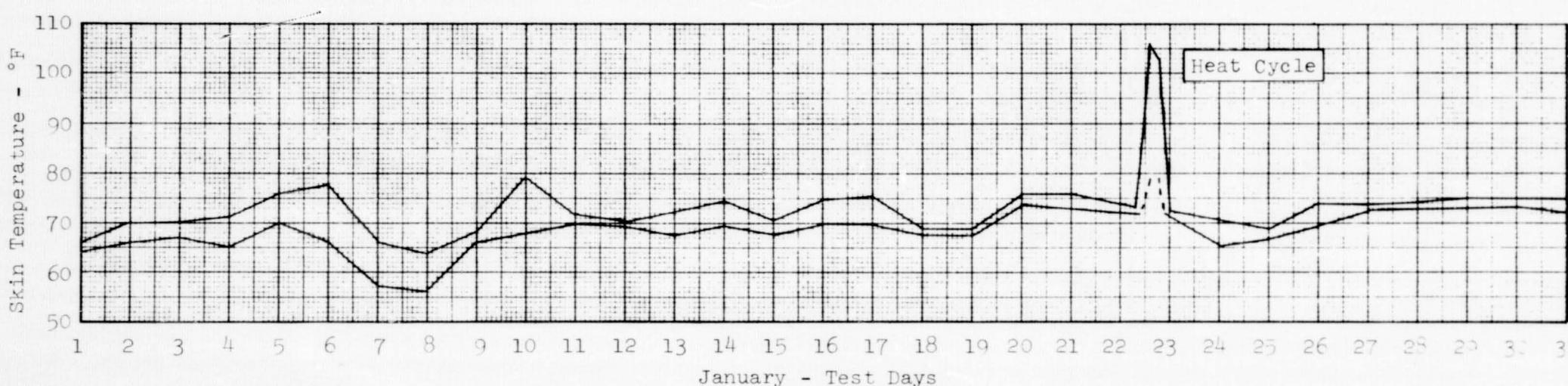
LM OXIDIZER TANK SN 039, ONE YEAR STORAGE TEST - N₂O₄



Sampled and
Drained Ullage

Flange Seal
Leak Test

Maximum and Minimum
Value Plotted For
Each 24 Hour Period



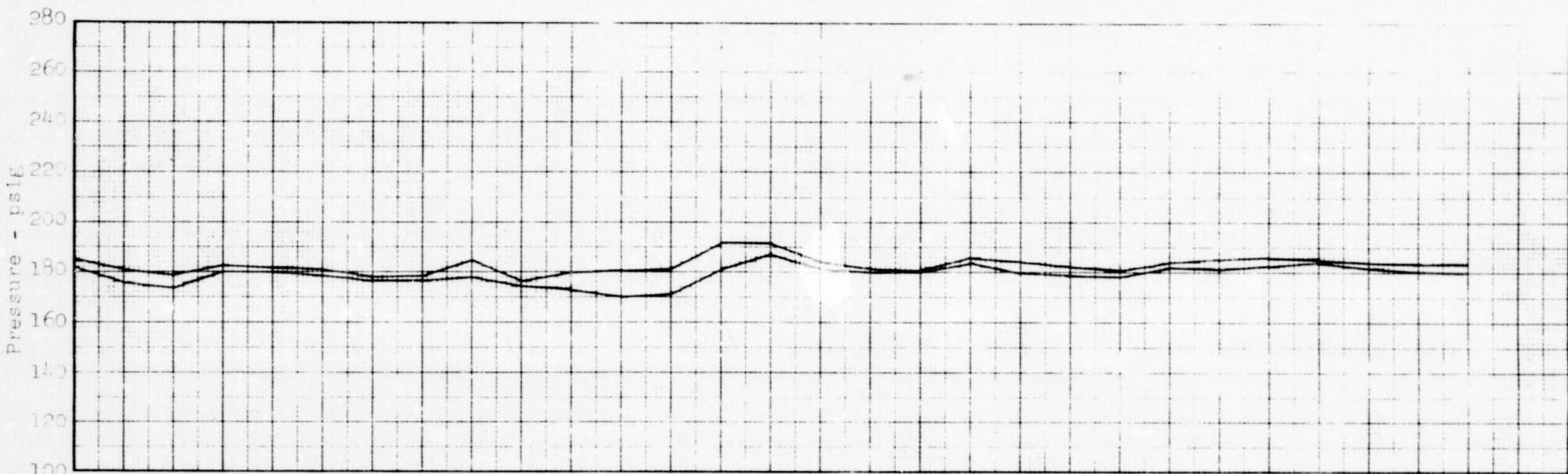
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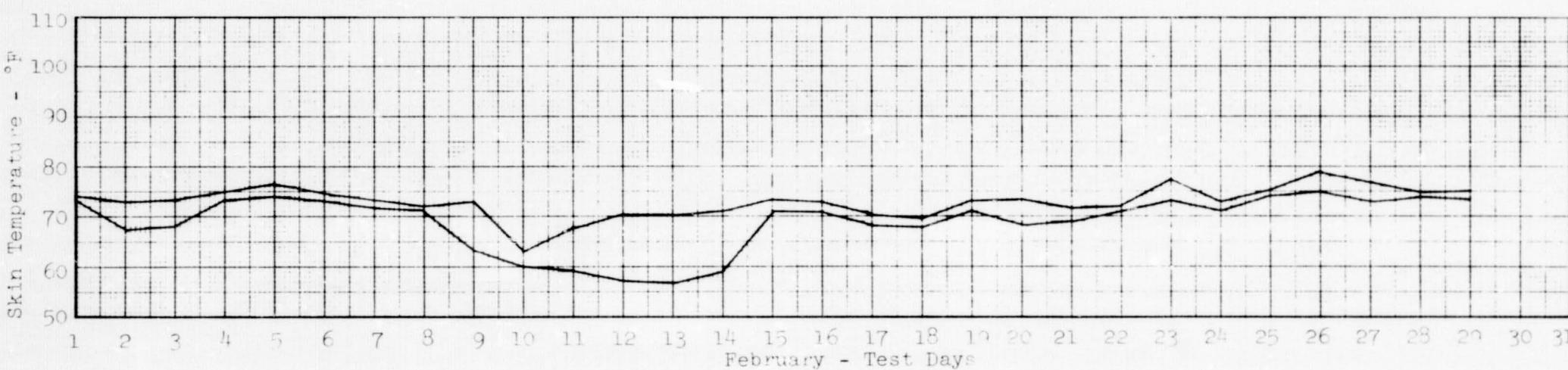


Sampled and
Drained Ullage

Tank
X-Rayed

Maximum and Minimum
Value Plotted for
Each 24 Hour Period

Flange Seal
Leak Test

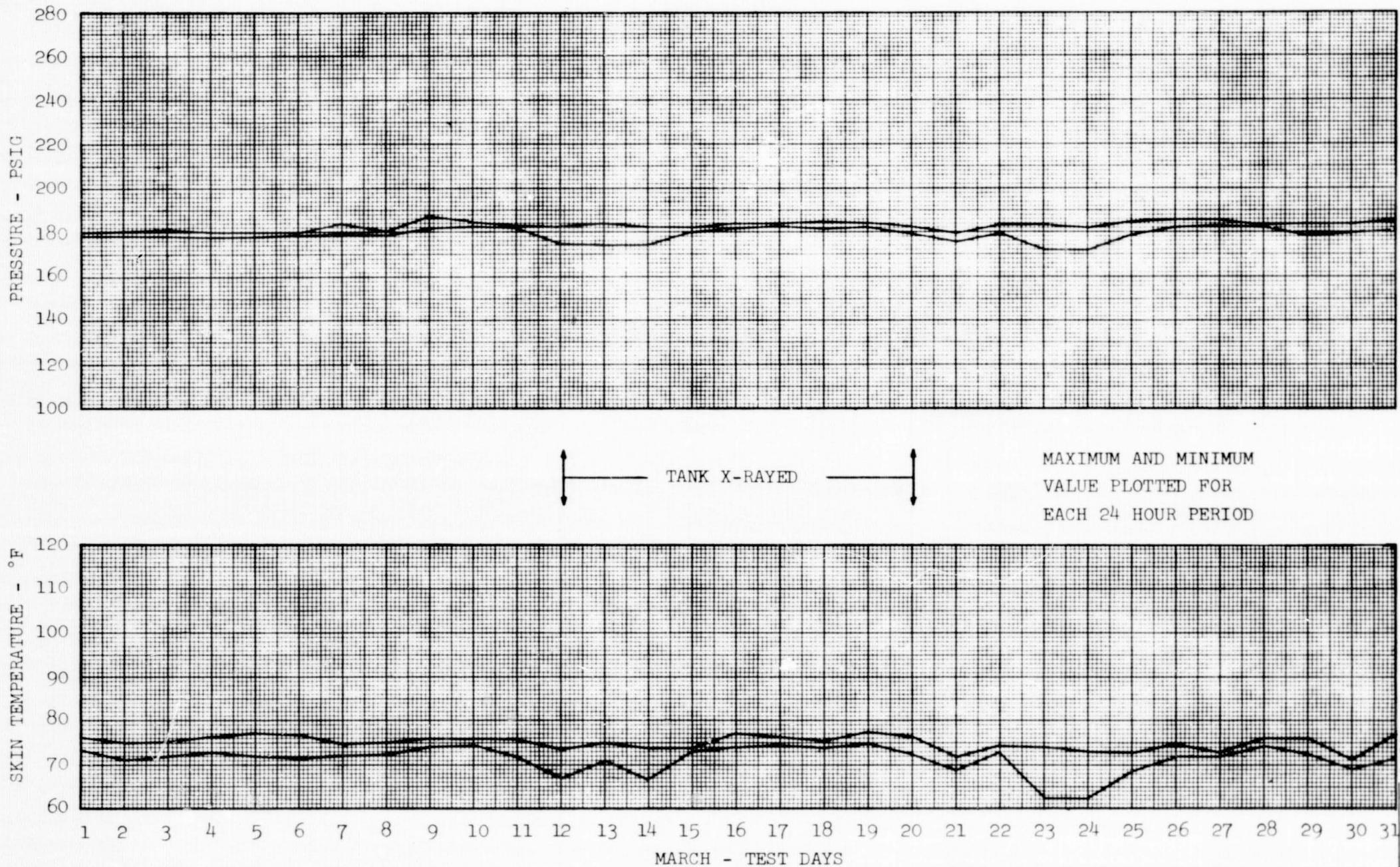


LM OXIDIZER SN 039, ONE YEAR STORAGE TEST - N₂O₄

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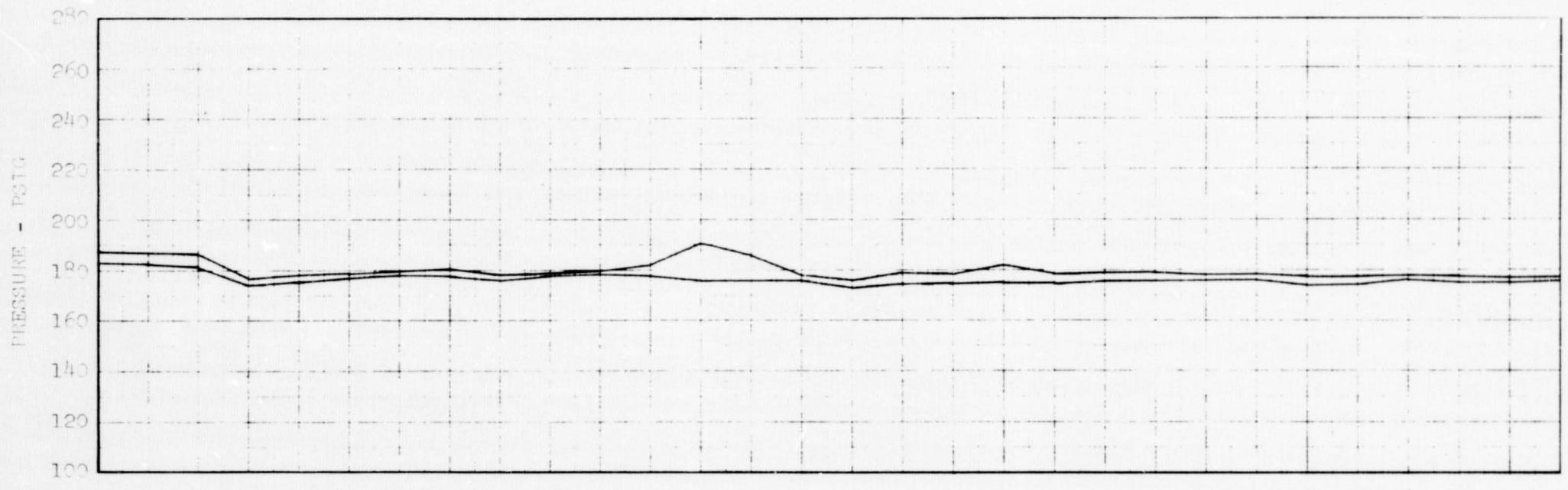
LM OXIDIZER TANK SNO39, ONE YEAR STORAGE TEST - N_2O_4

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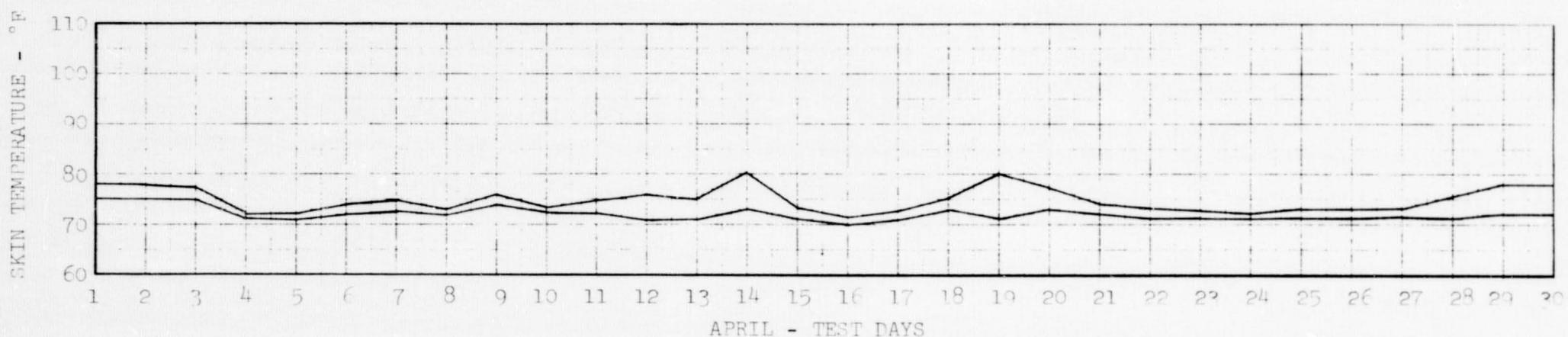
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MAXIMUM AND MINIMUM
VALUE PLOTTED FOR
EACH 24 HOUR PERIOD

TANK
X-RAYED

FLANGE SEAL
LEAK CHECK

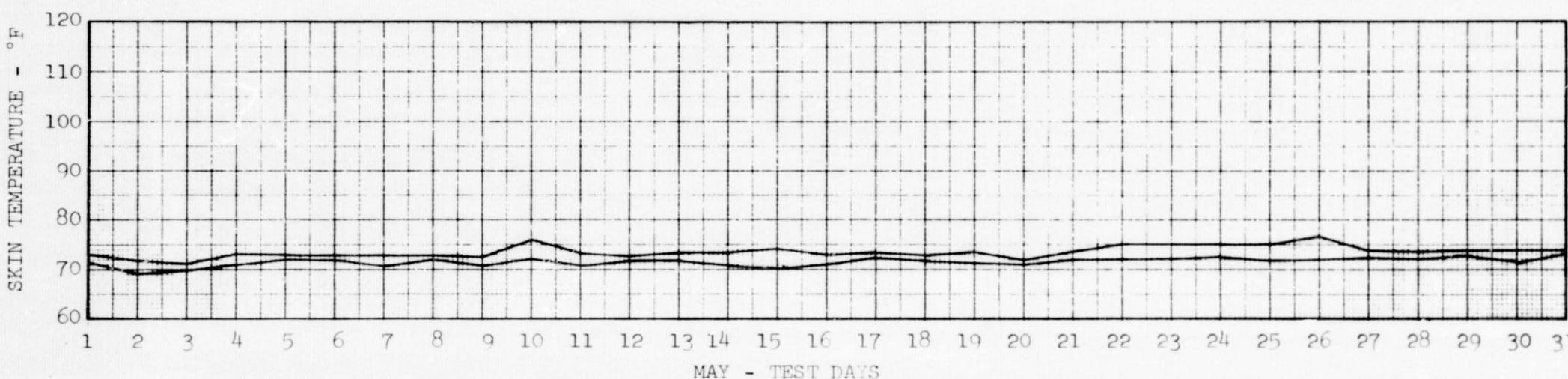
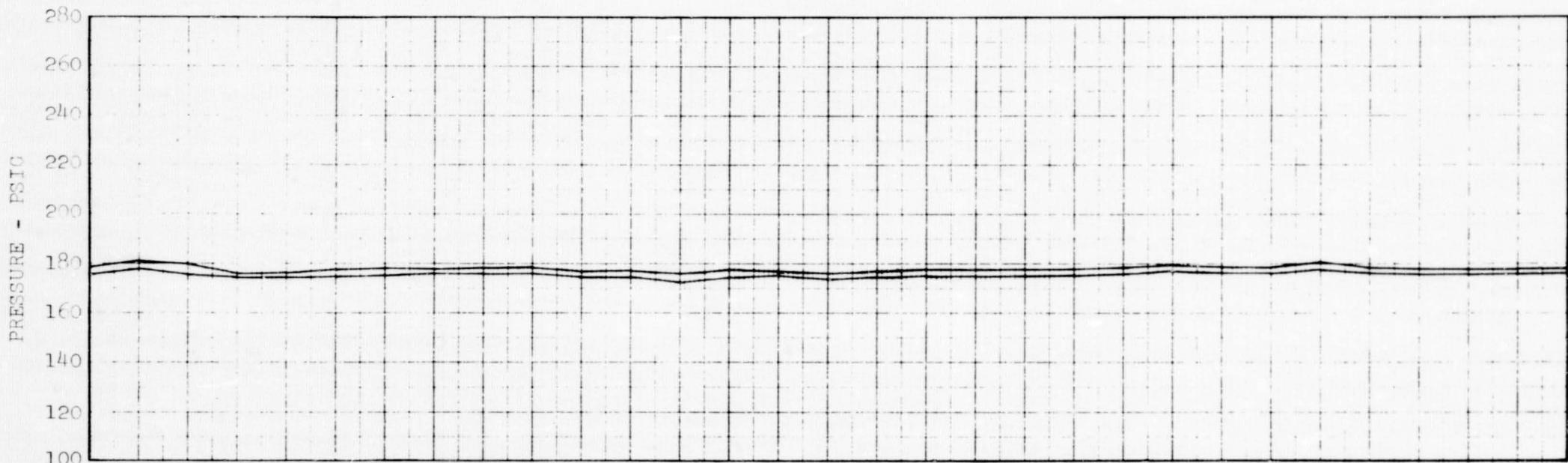


LM OXIDIZER TANK SNO39. ONE YEAR STORAGE TEST - N_2O_4

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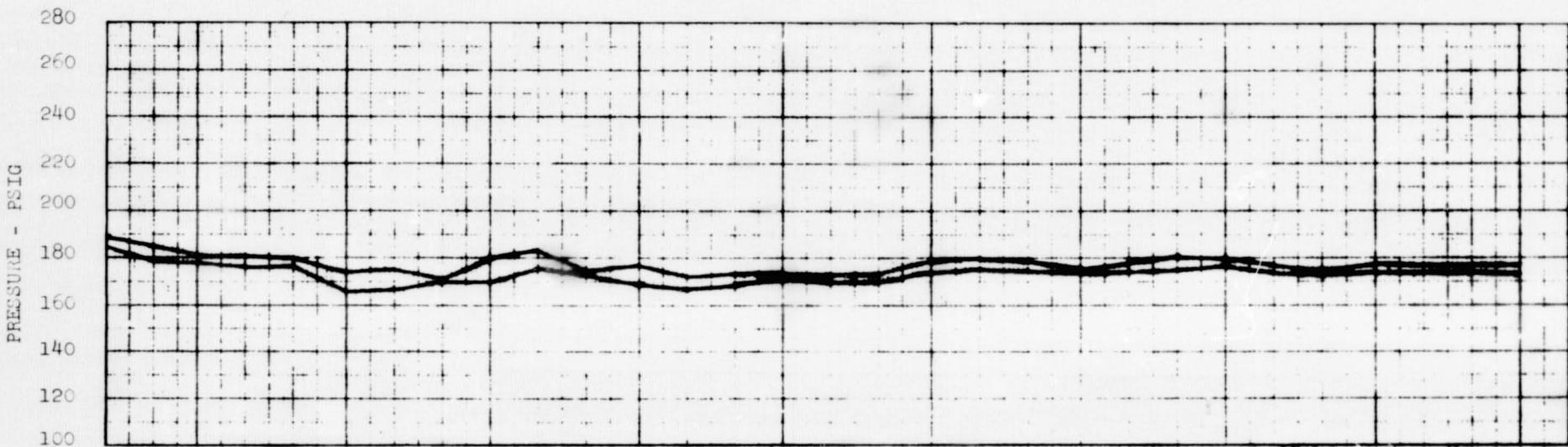
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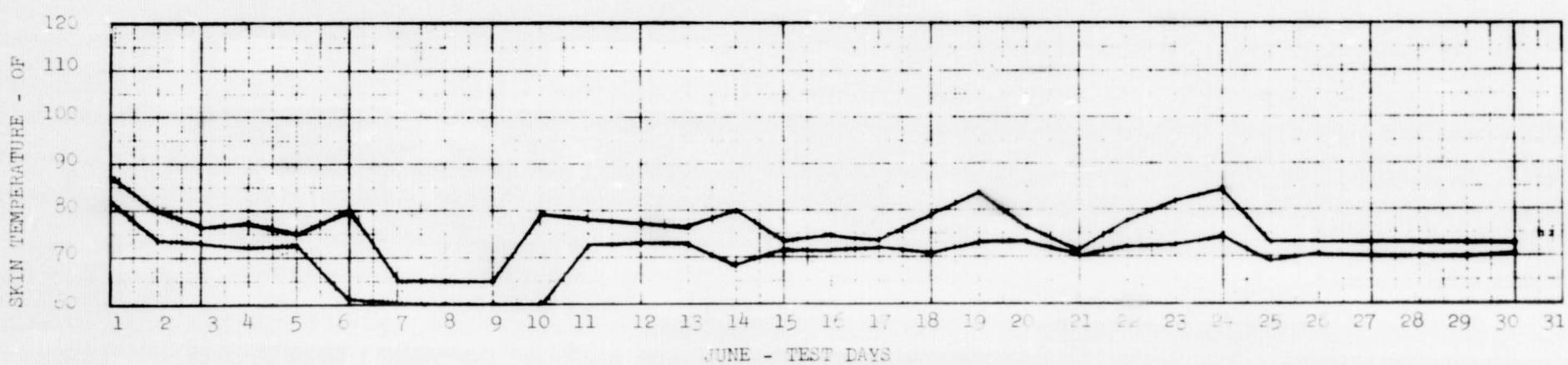
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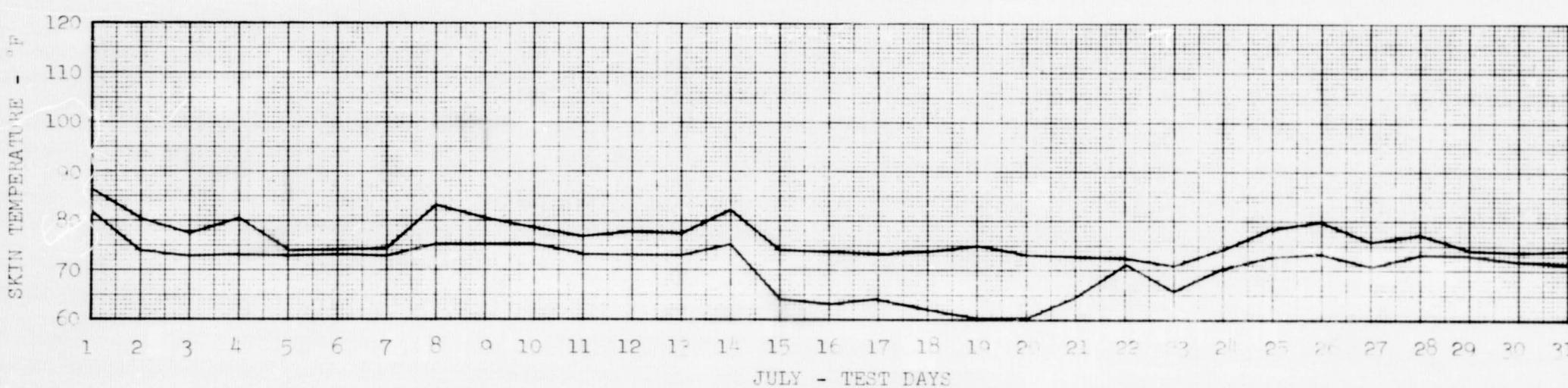
FLANGE SEAL
LEAK TEST

TANK
X - RAYED

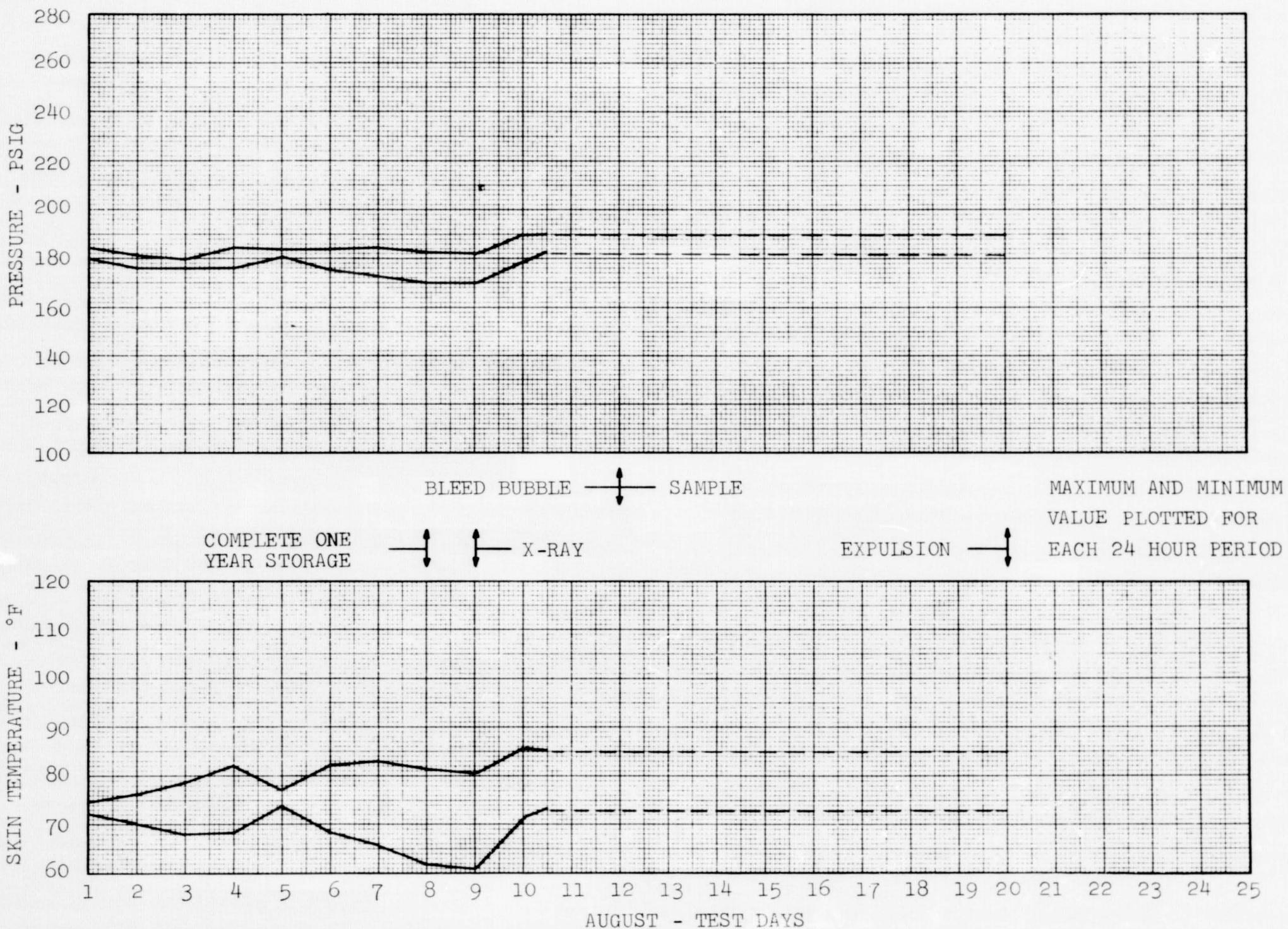
MAXIMUM AND MINIMUM
VALUE PLOTTED FOR
EACH 24 HOUR PERIOD



LM OXIDIZER TANK SN 039, ONE YEAR STORAGE TEST - N₂O₄



LM OXIDIZER TANK SN 029. ONE YEAR STORAGE TEST - N₂O₄



LM OXIDIZER TANK SN 039, ONE YEAR STORAGE TEST - N₂O₄

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BELL AEROSYSTEMS COMPANY

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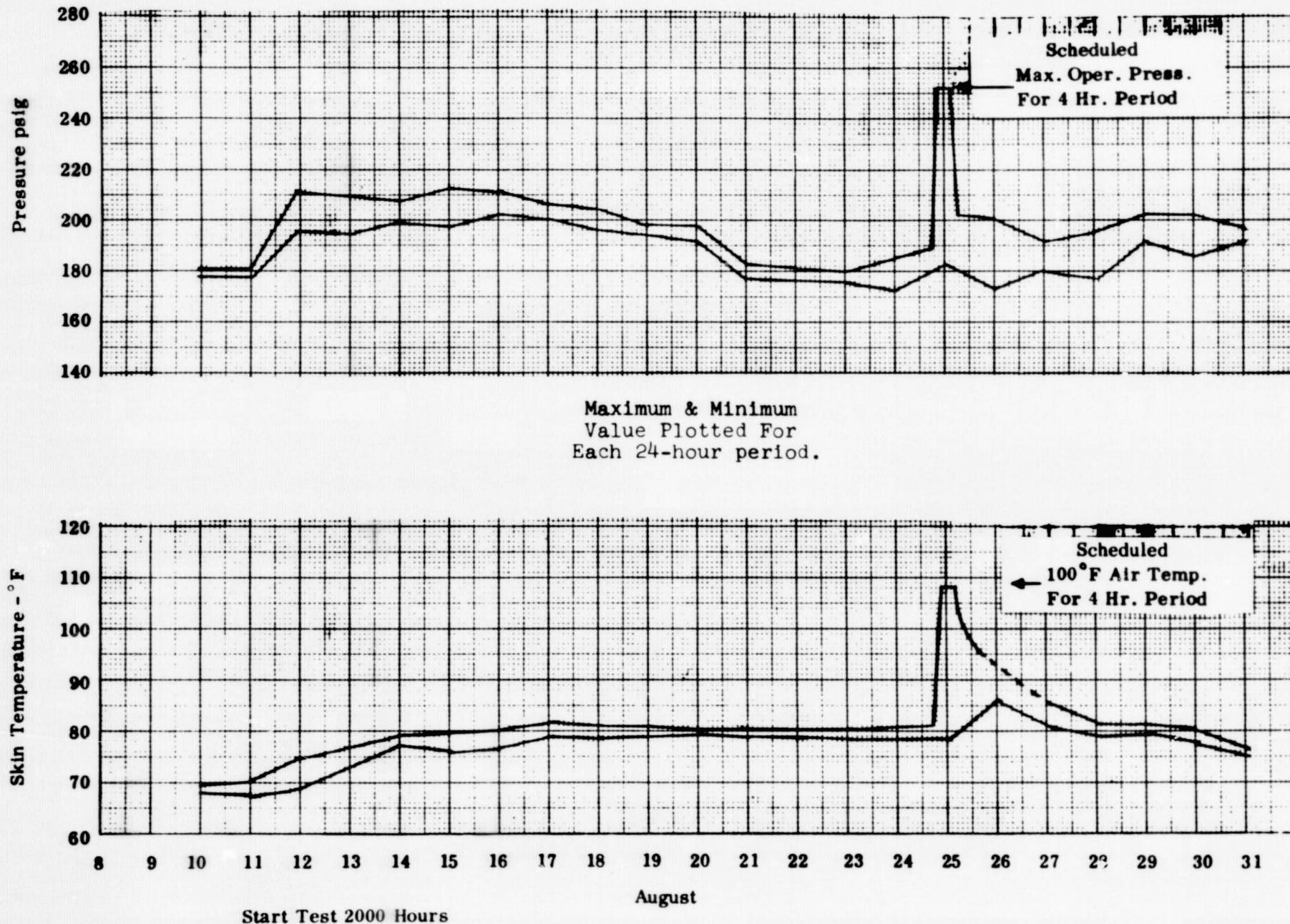
Issue _____ Date _____

APPENDIX II

LMF SN39 ONE YEAR STORAGE

Minimum and Maximum Pressure

and Temperature Each Day

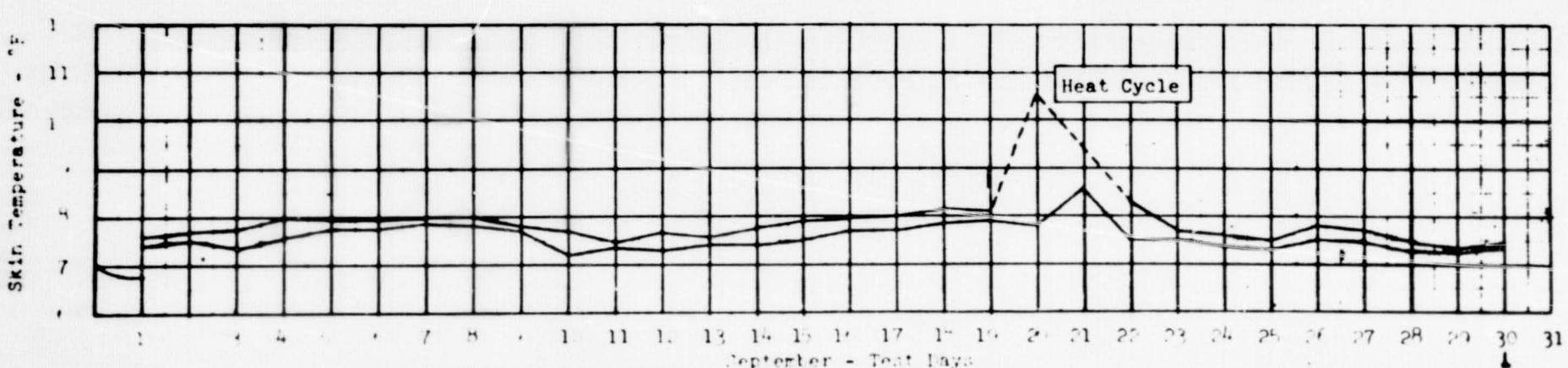
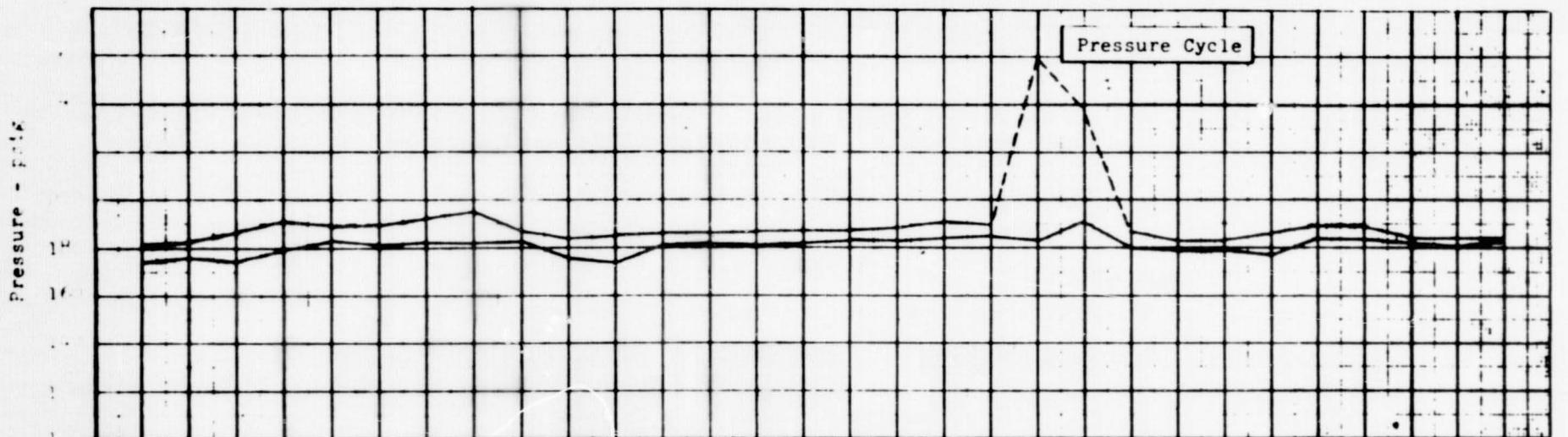


LM FUEL TANK SN 039, ONE YEAR STORAGE TEST - 50/50 BLEND

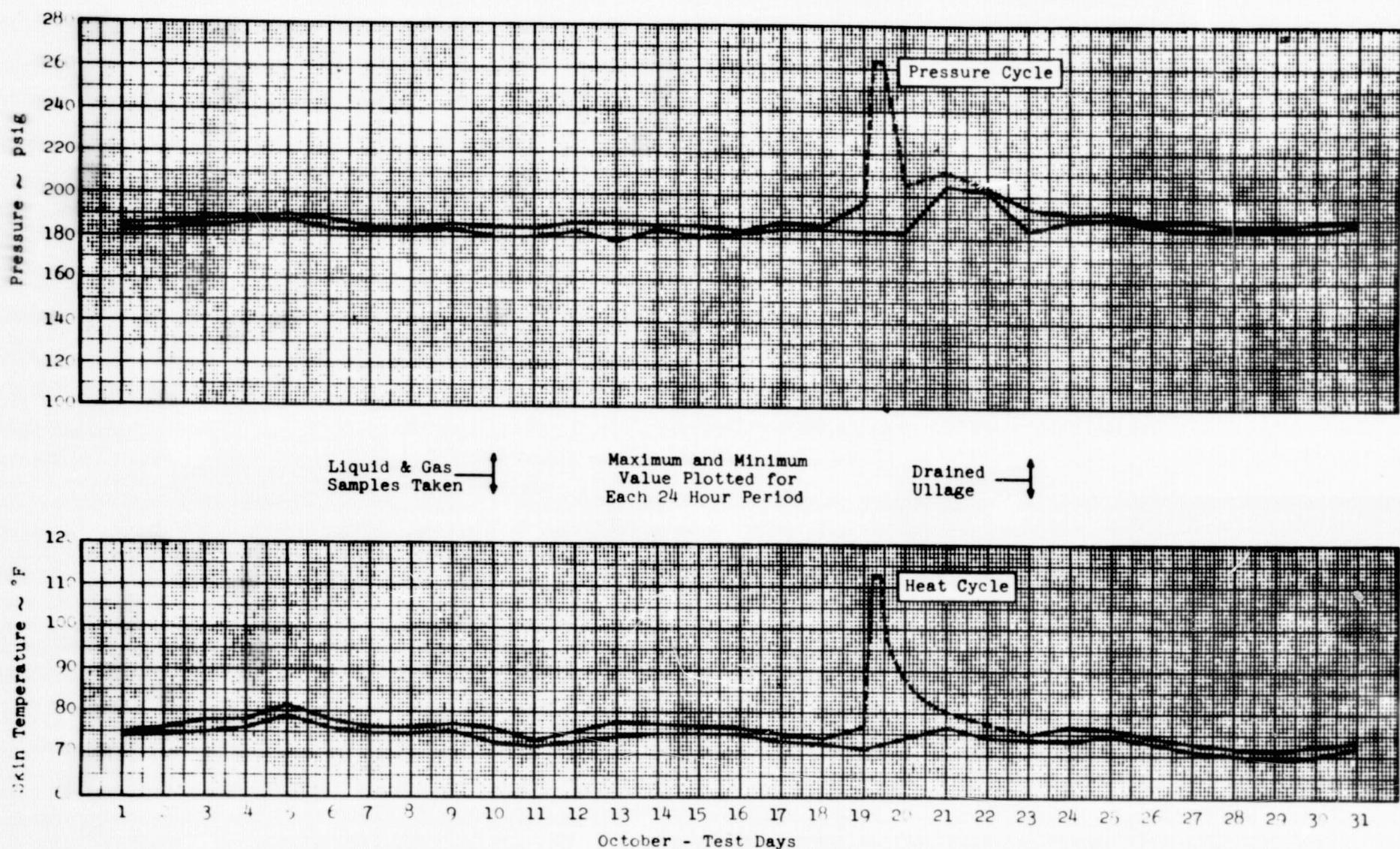
BELL AEROSYSTEMS COMPANY

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Report 8514-928004

Issue _____ Date _____



LM FUEL TANK SN 039, ONE YEAR STORAGE TEST - 50/50 BLEND



LM FUEL TANK SN 039, ONE YEAR STORAGE TEST - 50/50 BLEND

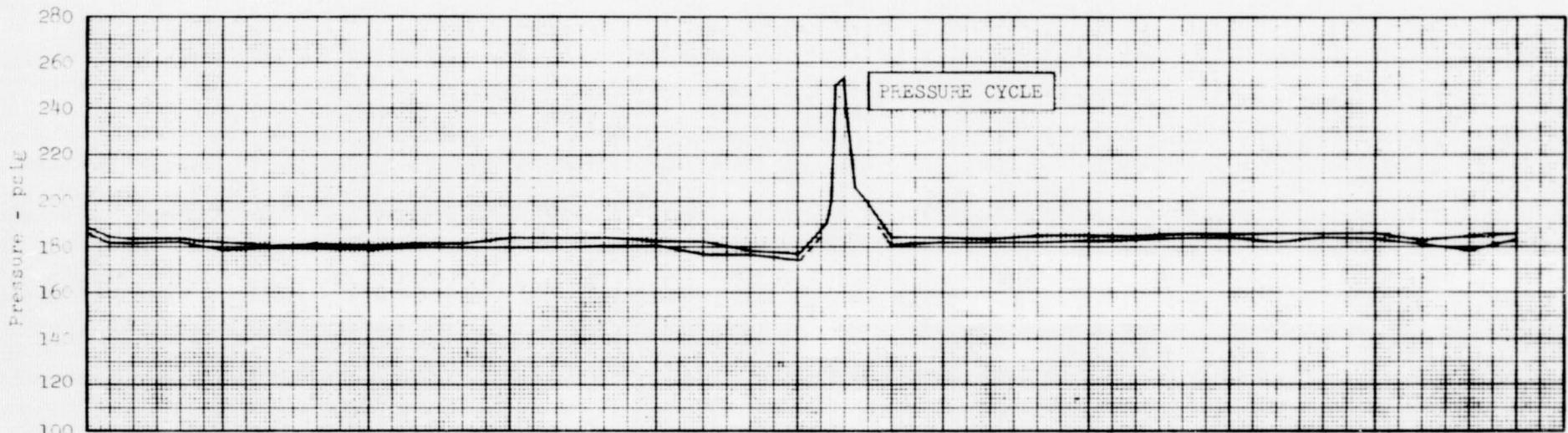
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BAC 0345A Rev. 26B

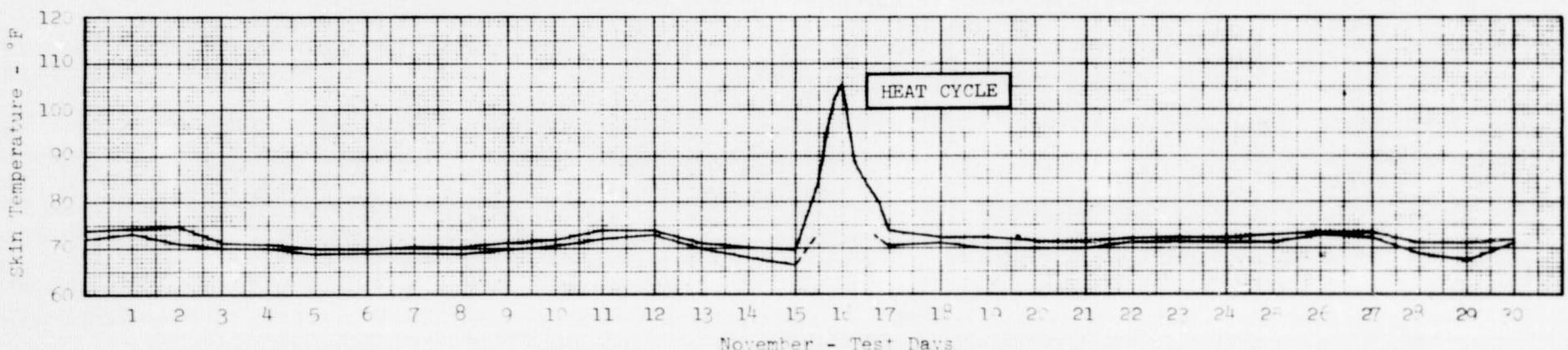
BELL AEROSYSTEMS COMPANY

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Report 8514-928004

Issue _____ Date _____



Sampled
Drained* Ullage
Flange Seal Leak Test
Maximum and Minimum Value Plotted for Each 24 Hour Period



November - Test Days

* - Pressure Dropped to 128 psig During Ullage Draining

LM FUEL TANK SN 329
ONE YEAR TEST 80/80 LEAD

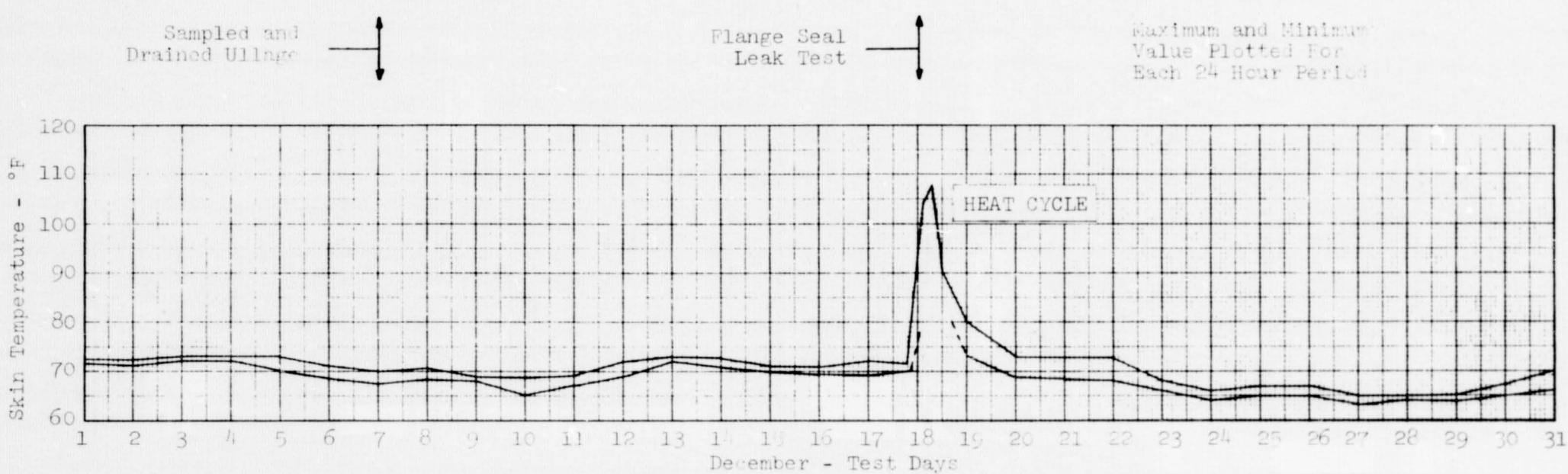
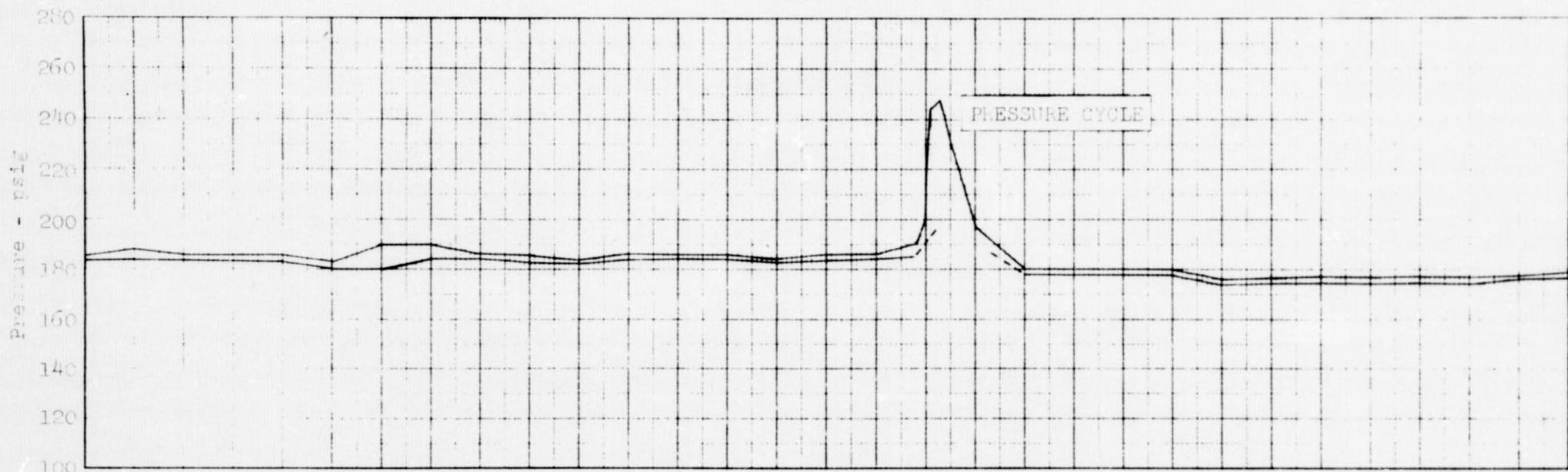
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BAL U545A Rev. Zb8

BELL AEROSYSTEMS COMPANY

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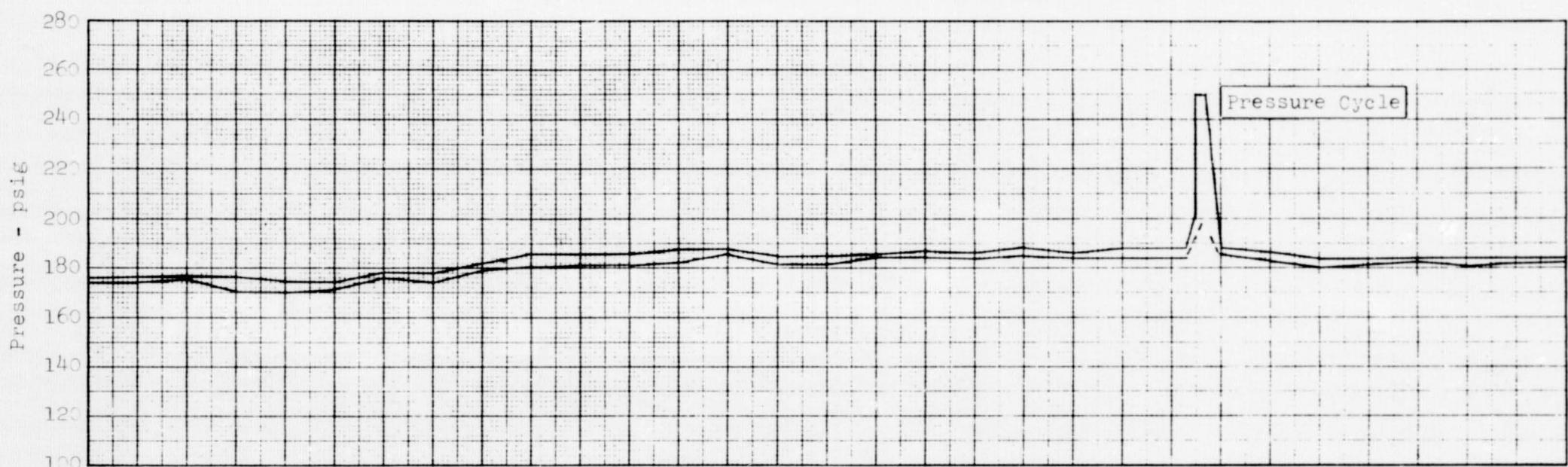
Issue _____ Date _____



LM FUEL TANK SN 039, ONE YEAR STORAGE TEST - 50/50 BLEND

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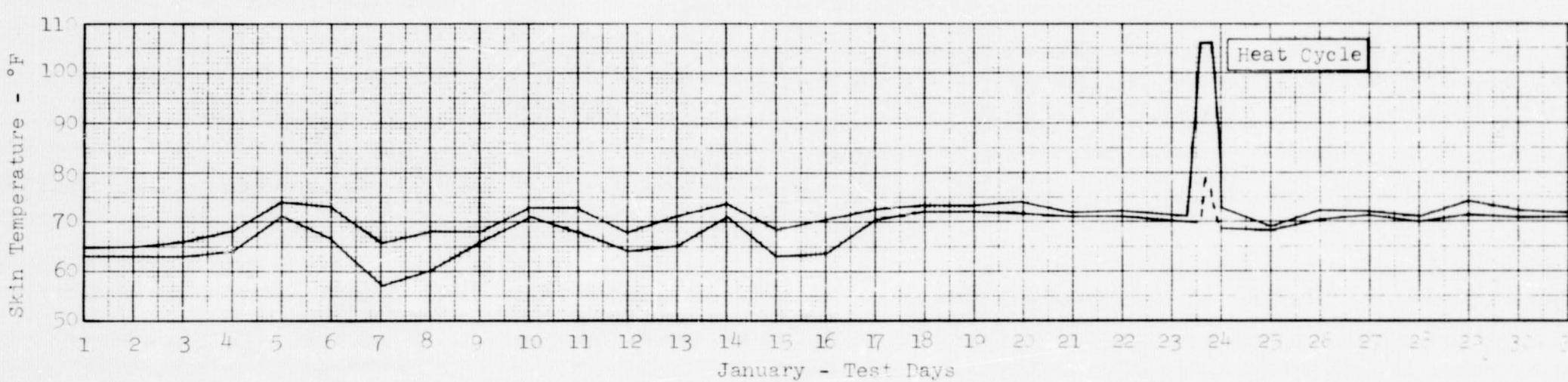
Issue _____ Date _____



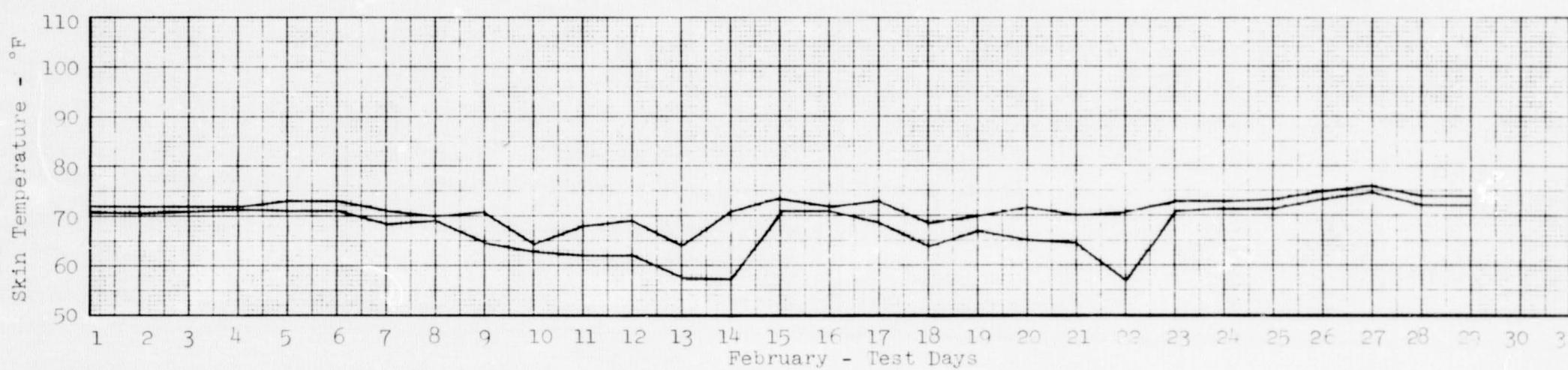
Sampled and
Drained Ullage

Flange Seal
Leak Test

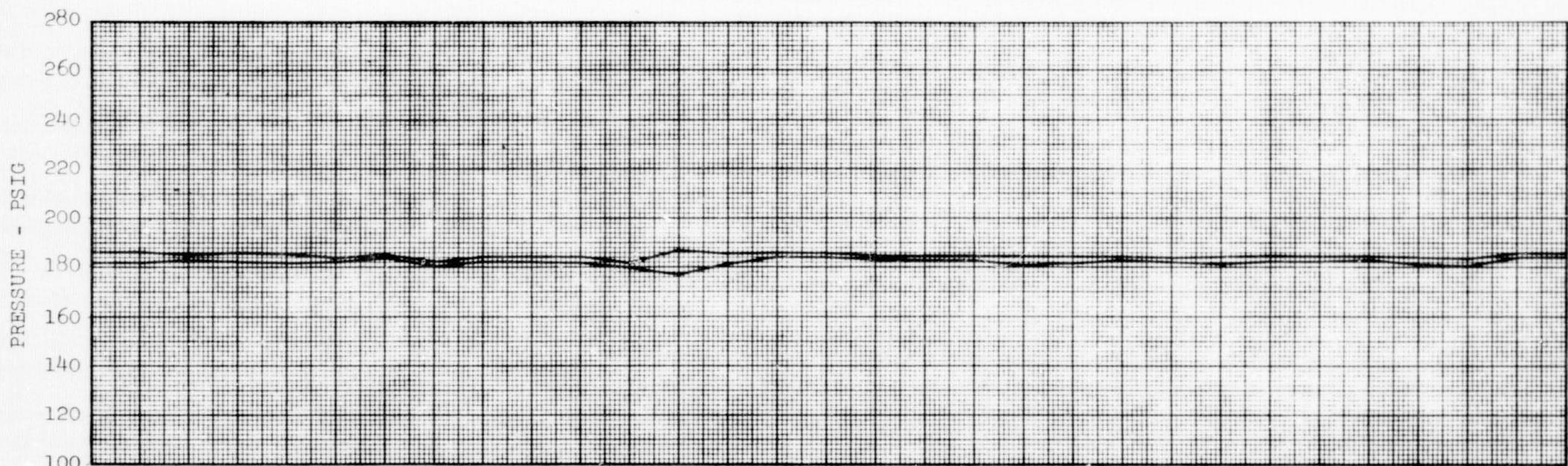
Maximum and Minimum
Value Plotted For
Each 24 Hour Period



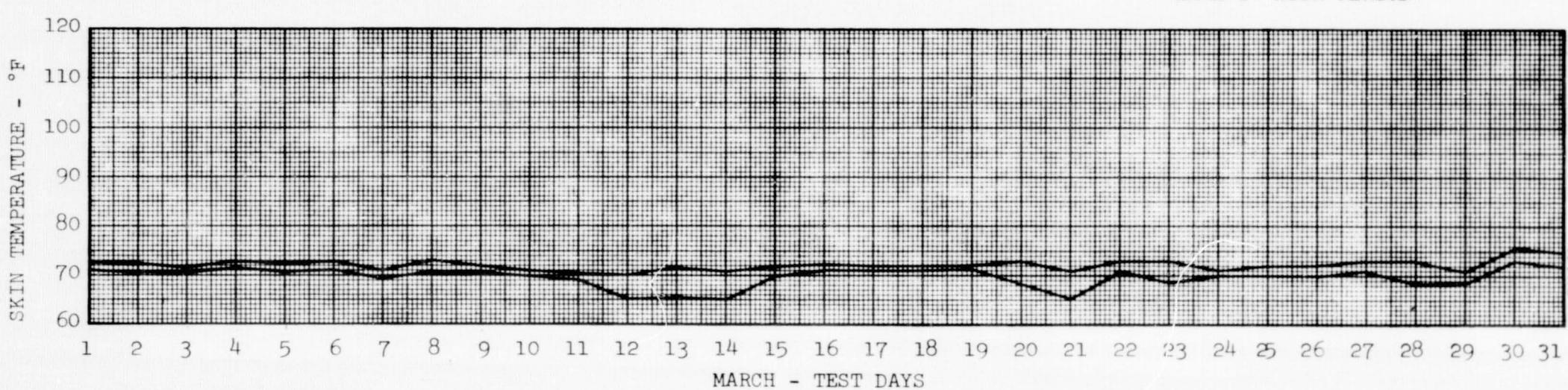
LM FUEL TANK SN 339, ONE YEAR STORAGE TEST - 50/50 BLEND



LM FUEL TANK SN 039, ONE YEAR STORAGE TEST - 50/50 BLEND



MAXIMUM AND MINIMUM
VALUE PLOTTED FOR
EACH 24 HOUR PERIOD



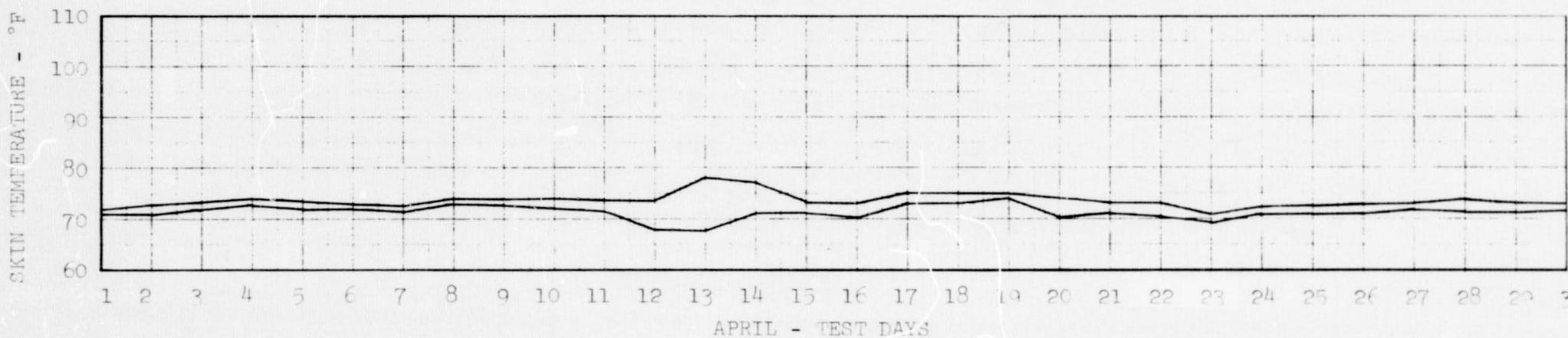
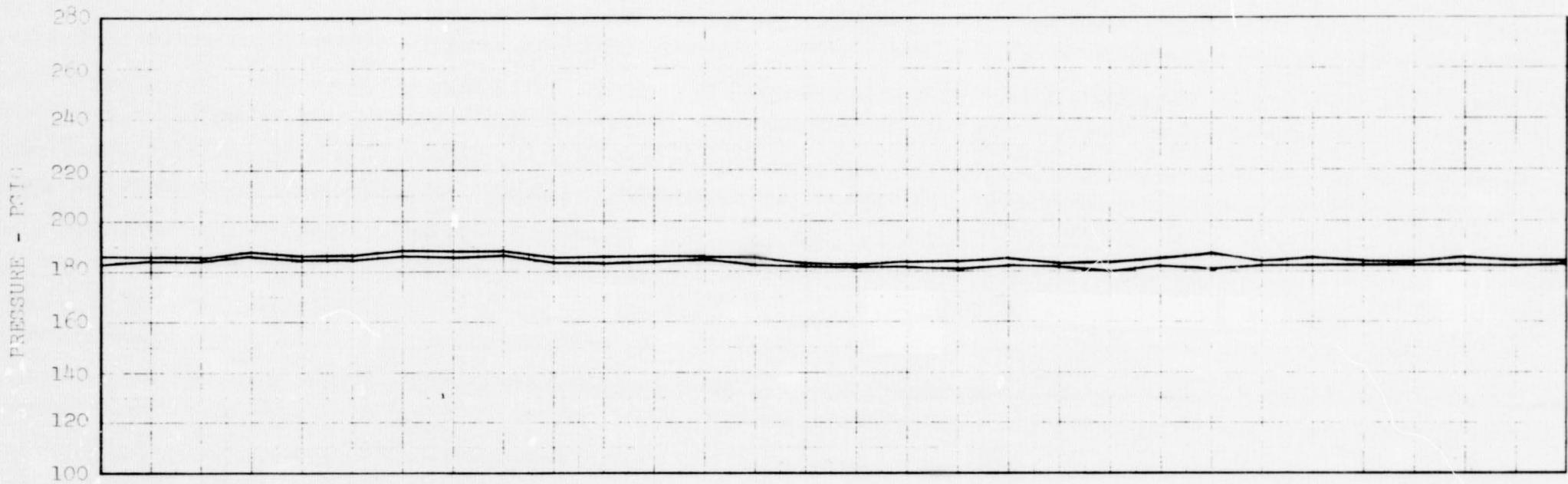
LM FUEL TANK SNO39, ONE YEAR STORAGE TEST - 50/50 BLEND

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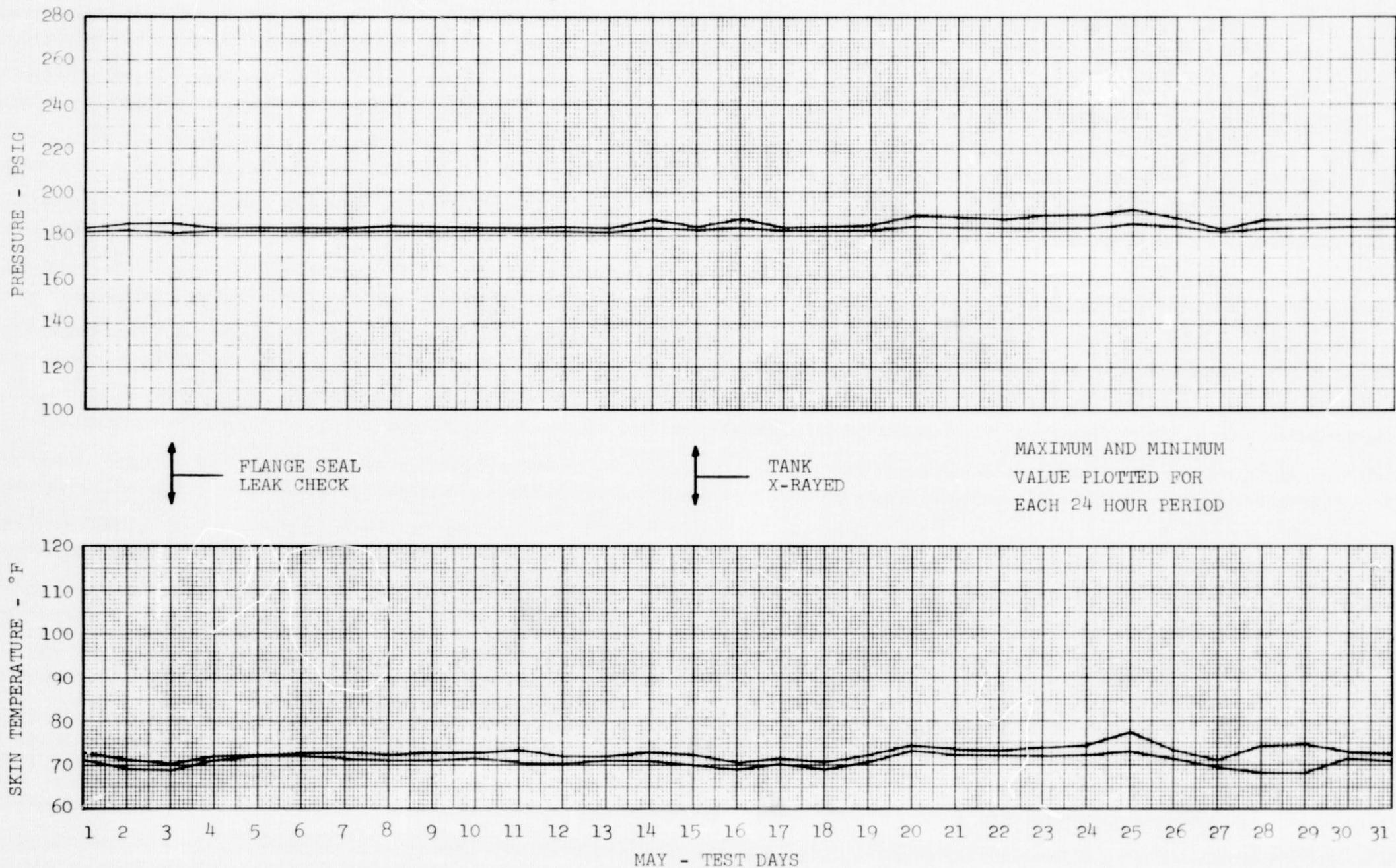
BAC 0345A Rev. 268

BELL AEROSYSTEMS COMPANY

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Report 8514-928004
Issue _____ Date _____



LM FUEL TANK SNO39, ONE YEAR STORAGE TEST - 50/50 BLEND



LM FUEL TANK SNO39, ONE YEAR STORAGE TEST - 50/50 BLEND

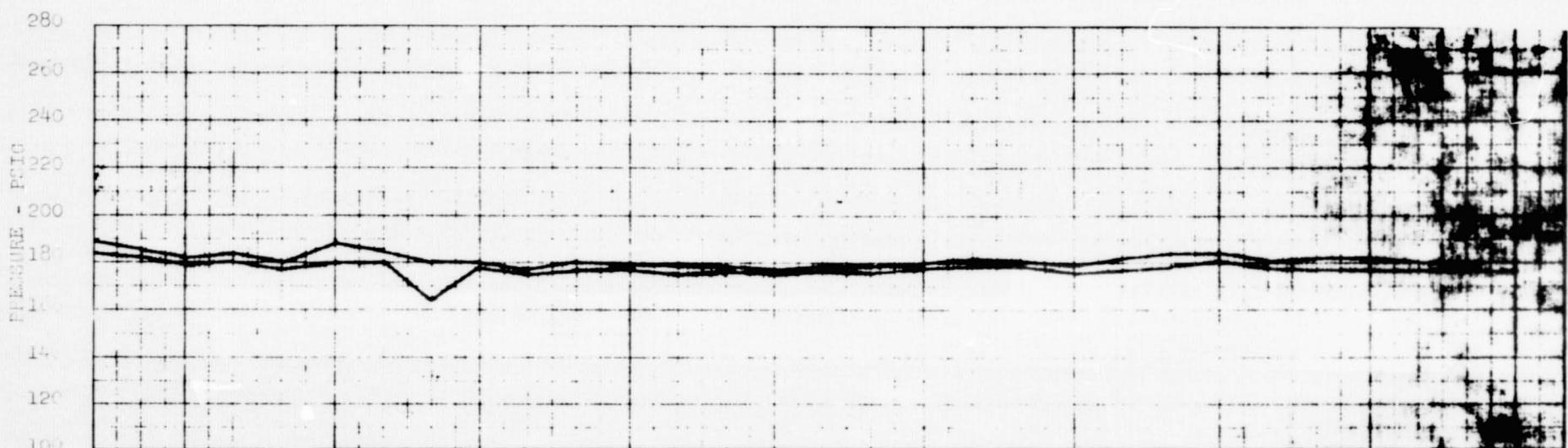
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BAC 0345A Rev. 268

BELL AEROSYSTEMS COMPANY

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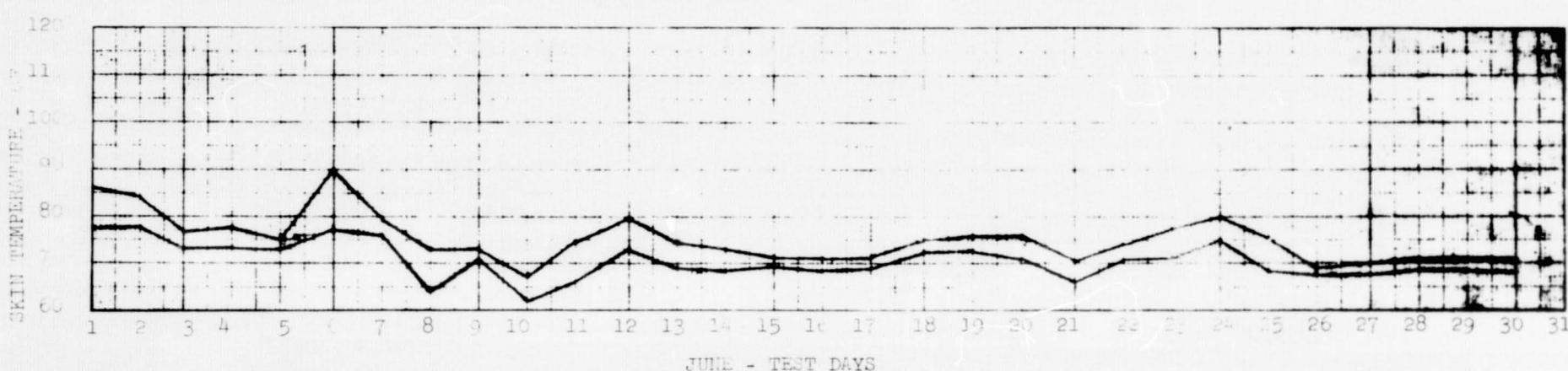
Issue _____ Date _____



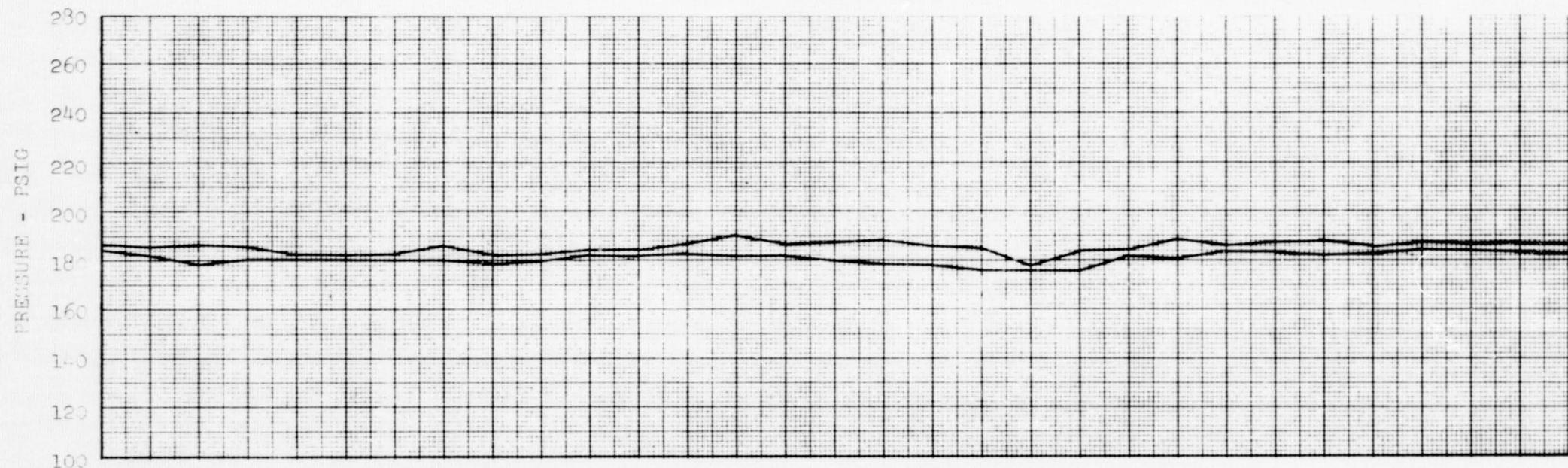
FLANGE SEAL
LEAK TEST

TANK
X-RAYED

MAXIMUM AND MINIMUM
VALUE PLOTTED FOR
EACH 24 HOUR PERIOD

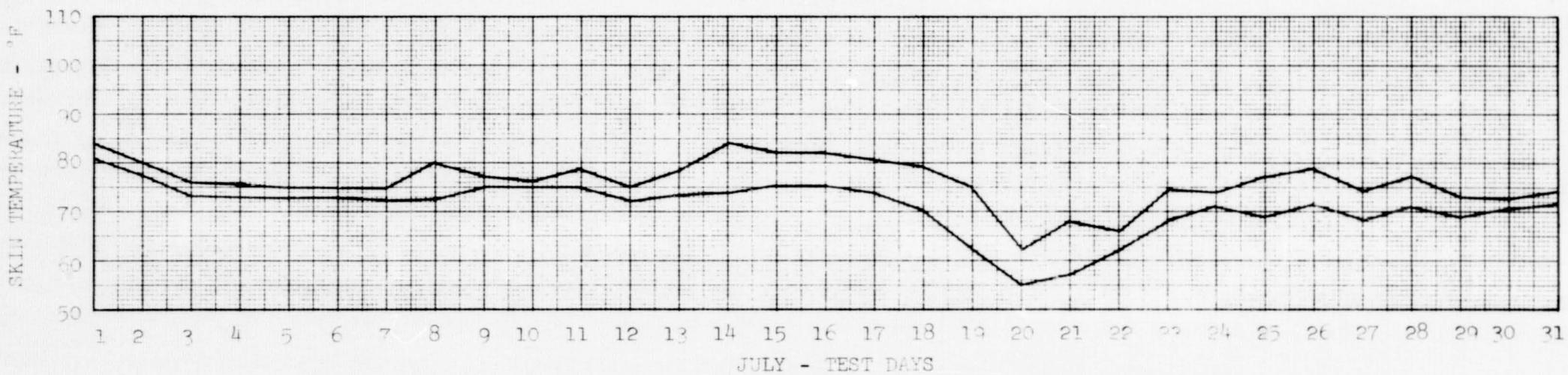


LM FUEL TANK SN 039, ONE YEAR STORAGE TEST - 50/50 BLEND

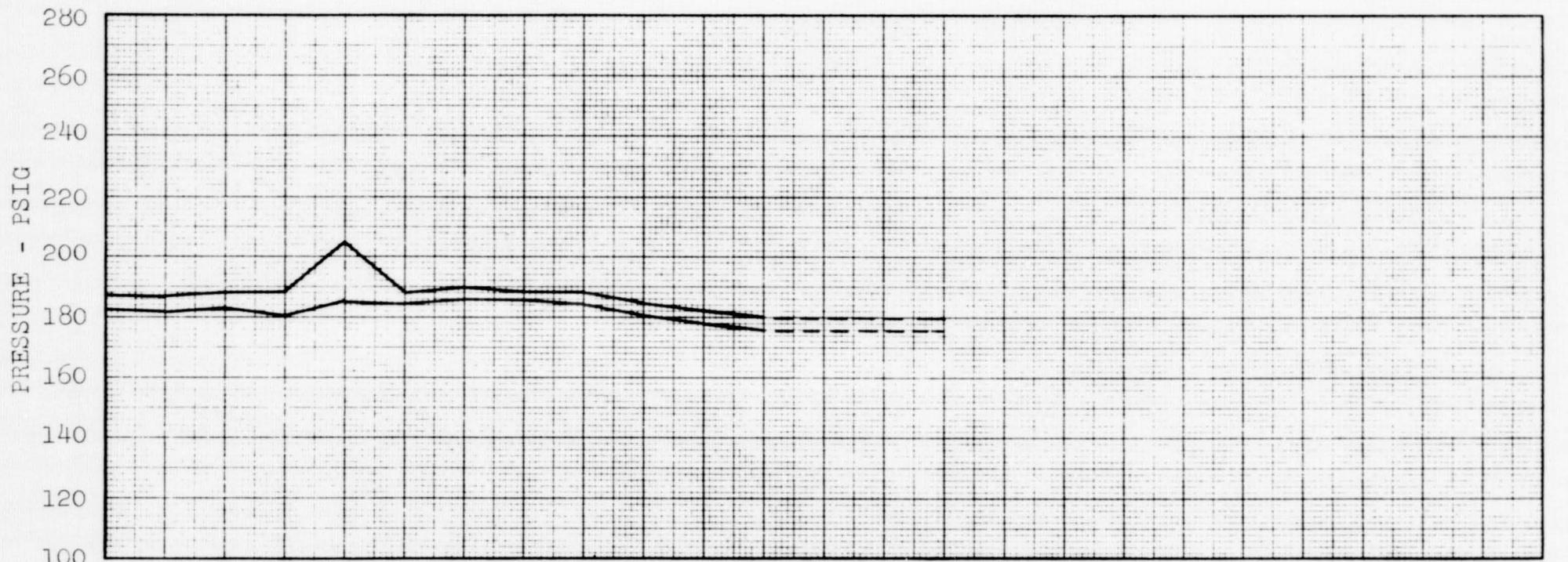


MAXIMUM AND MINIMUM
VALUE PLOTTED FOR
EACH 24 HOUR PERIOD

FLANGE SEAL
LEAK CHECK TANK
X-RAYED



LM FUEL TANK SN 039, ONE YEAR STORAGE TEST - 50/50 BLEND

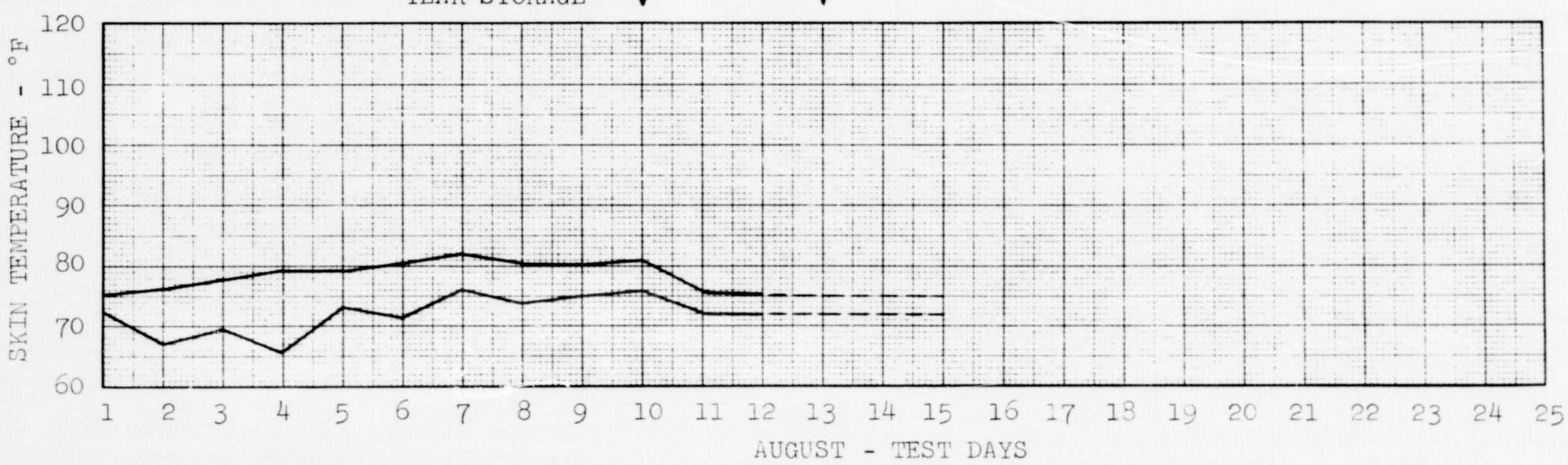


X-RAY SAMPLE EXPULSION

COMPLETE ONE
YEAR STORAGE

BLEED BUBBLE

MAXIMUM AND MINIMUM
VALUE PLOTTED FOR
EACH 24 HOUR PERIOD



AUGUST - TEST DAYS

LM FUEL TANK SN 039, ONE YEAR STORAGE TEST - 50/50 BLEND

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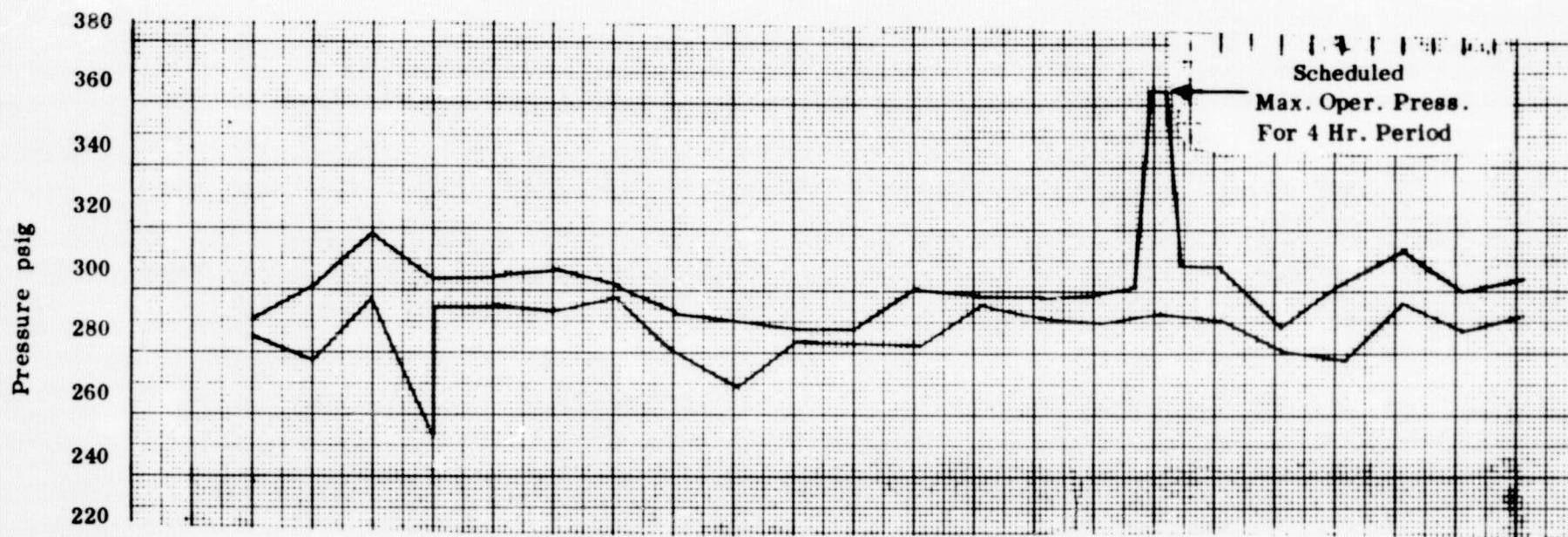
Issue _____ Date _____

APPENDIX III

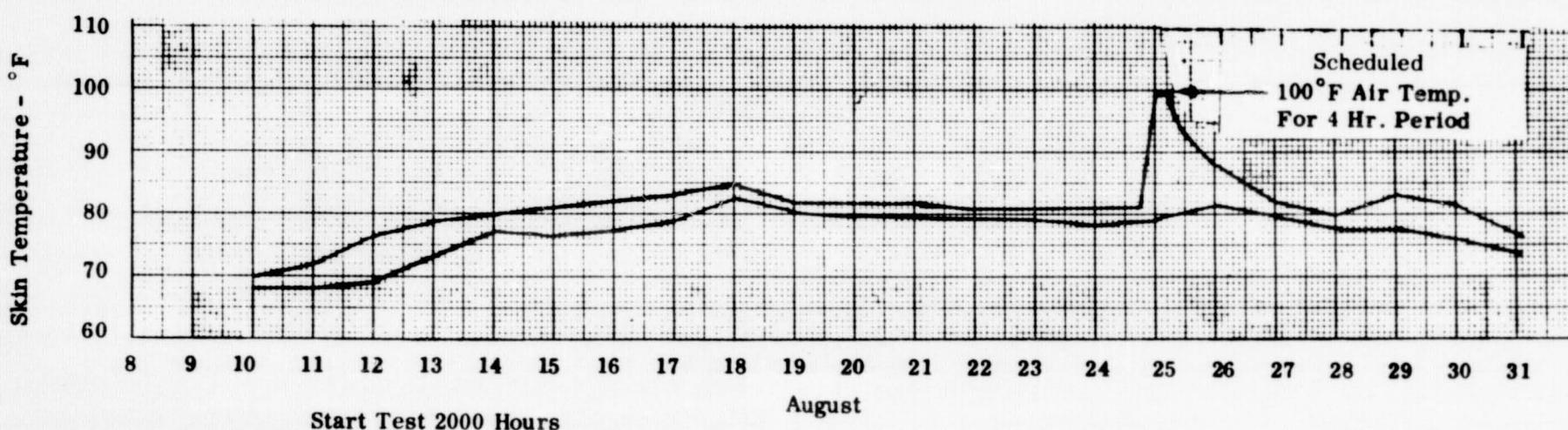
CMF SN 20 ONE YEAR STORAGE
MINIMUM AND MAXIMUM PRESSURE
AND TEMPERATURE EACH DAY

Page III-2
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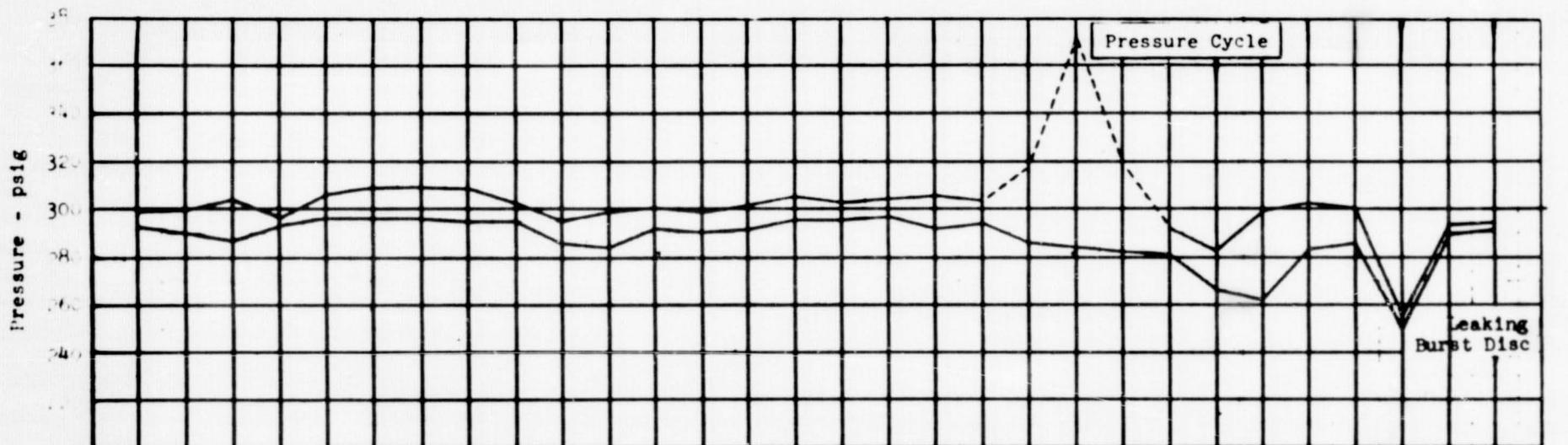
Issue _____ Date _____



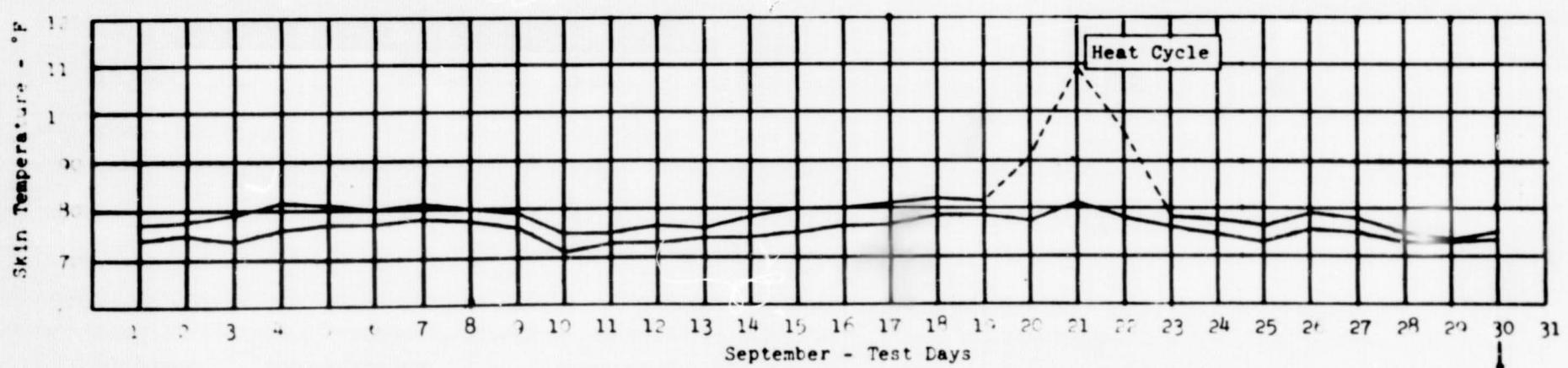
Maximum & Minimum Value Plotted For Each 24-hour Period.



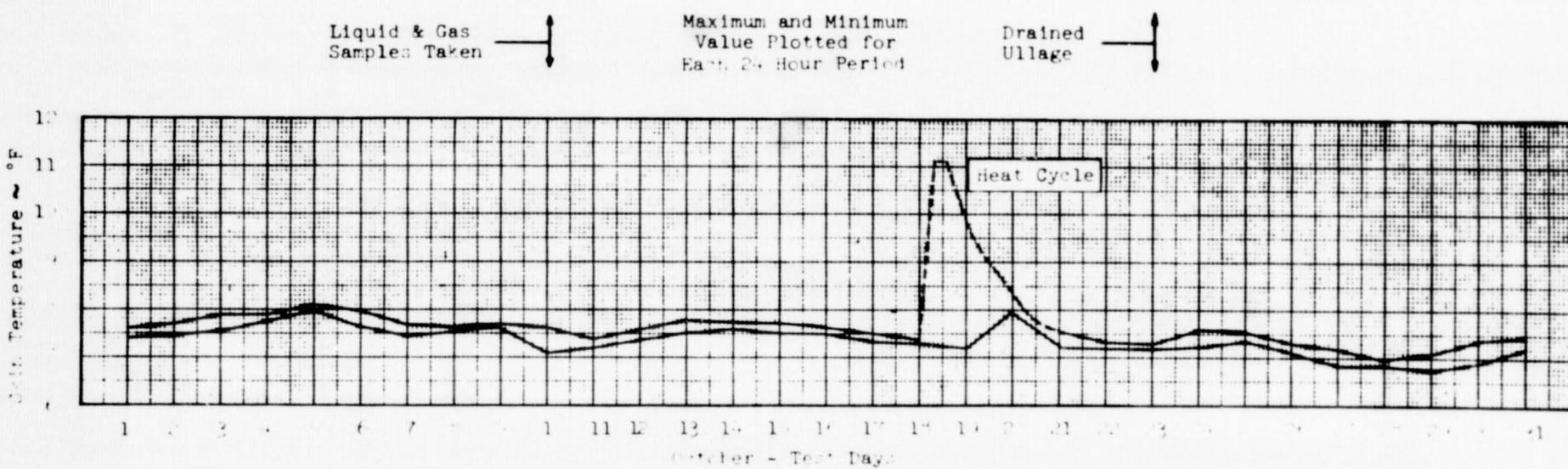
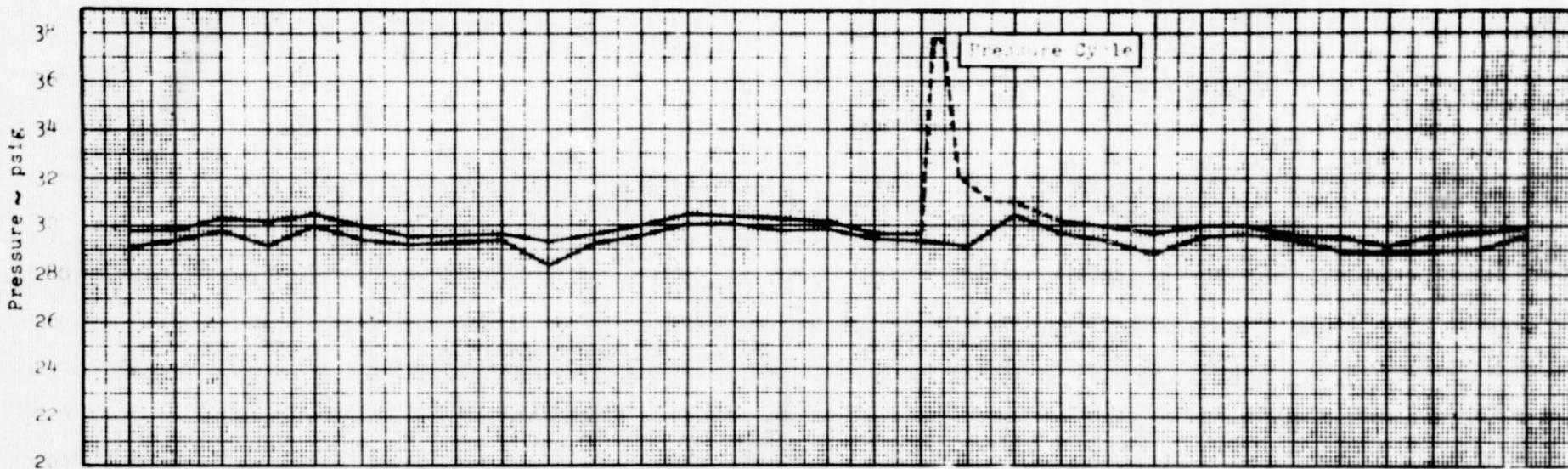
APOLLO CM FUEL TANK SN 020, ONE YEAR STORAGE TEST - MMH



▼ Maximum and Minimum
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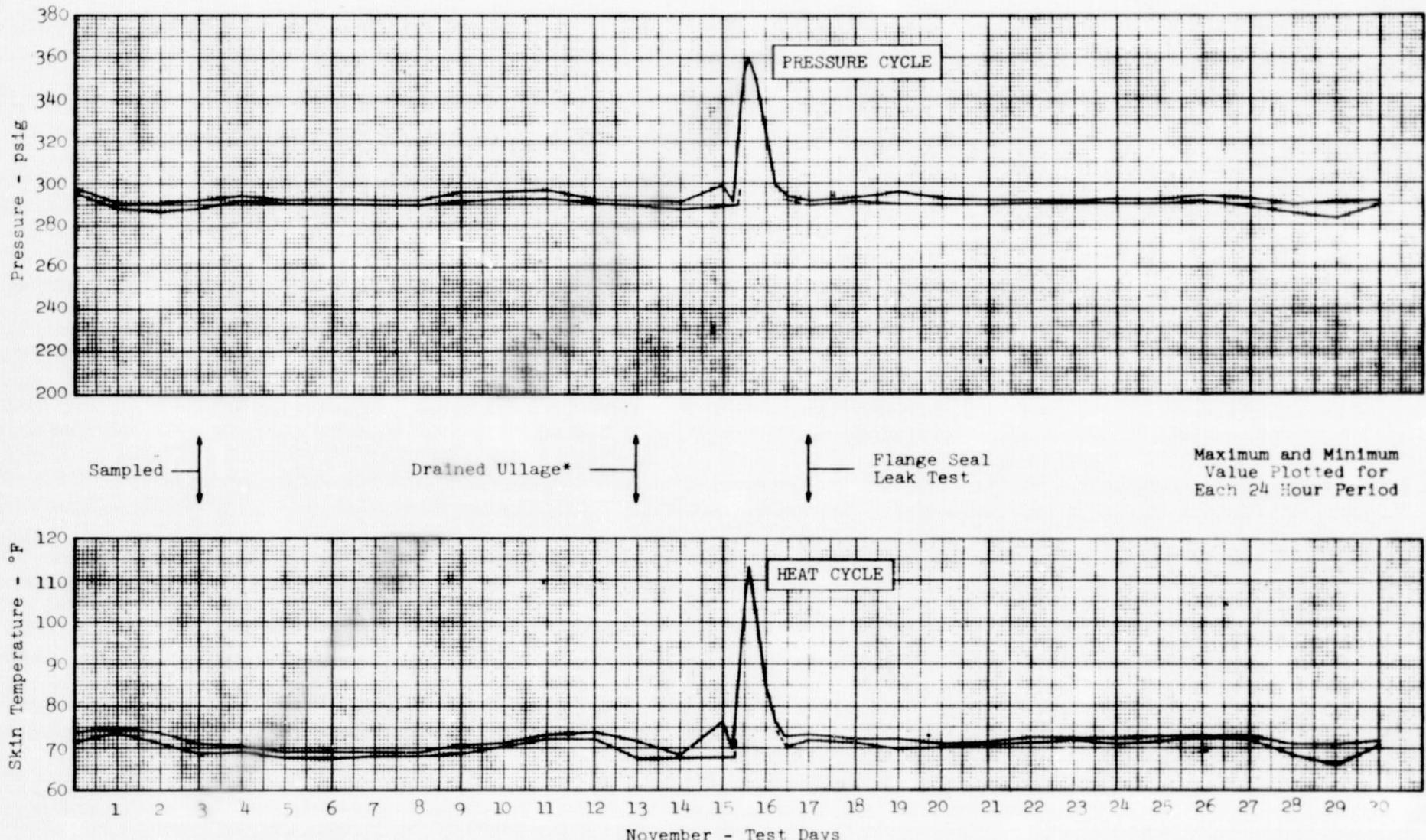


APOLLO CM FUEL TANK SN 020, ONE YEAR STORAGE TEST - MMH



APOLLO CM FUEL TANK SN 020, ONE YEAR STORAGE TEST - MMH

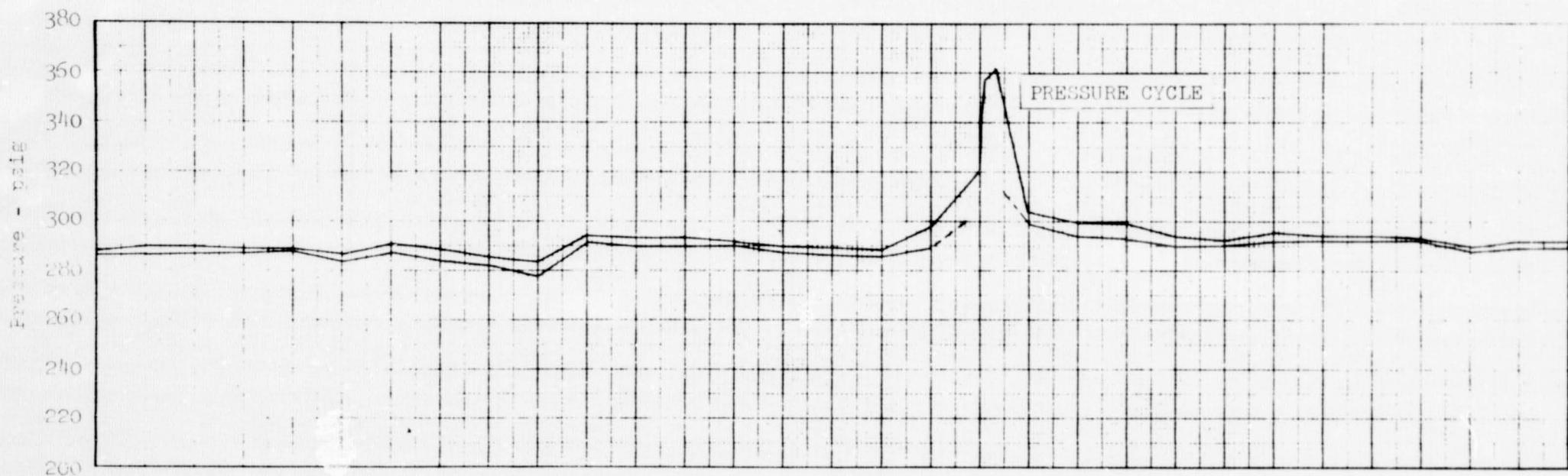
Issue _____ Date _____



* - Pressure Dropped to 209 psig
During Ullage Draining

APOLLO CM FUEL TANK SN 020
ONE YEAR STORAGE TEST - MMH

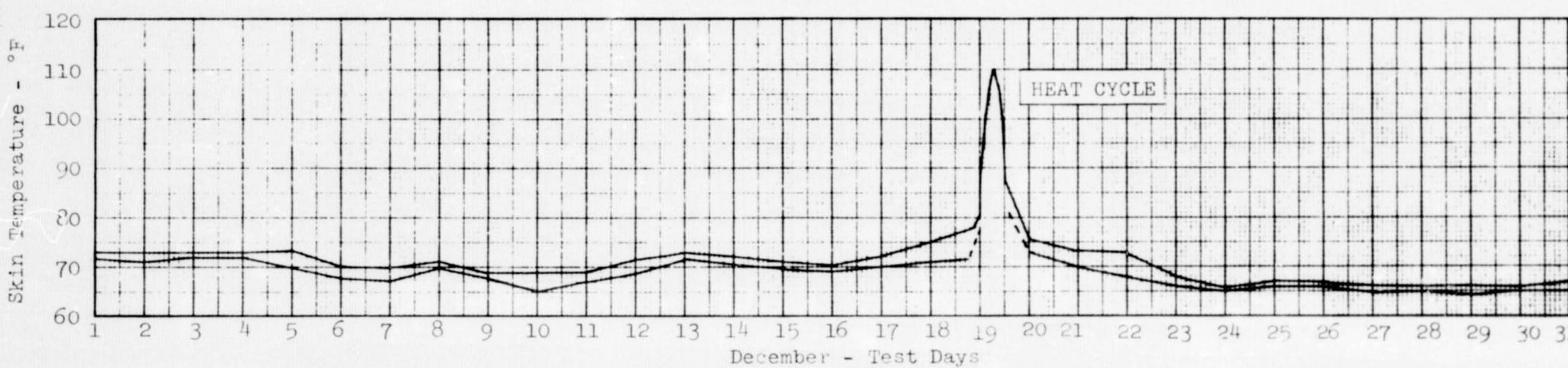
Page III-6
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 Issue _____ Date _____



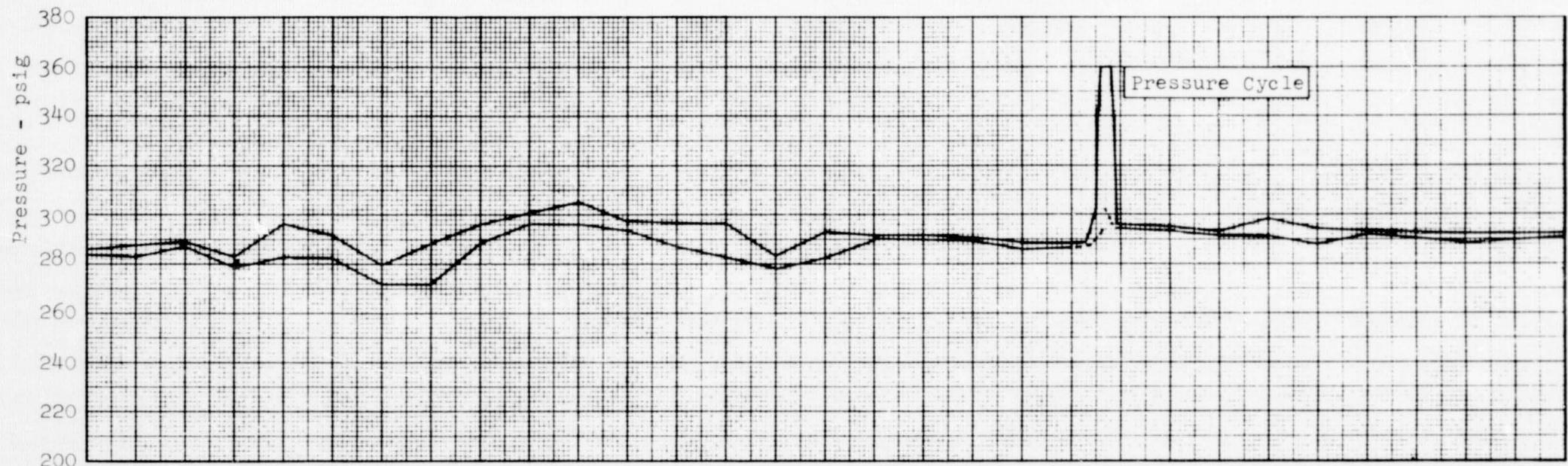
Sampled and Drained Ullage

Flange Seal Leak Test

Maximum and Minimum Value Plotted For Each 24 Hour Period



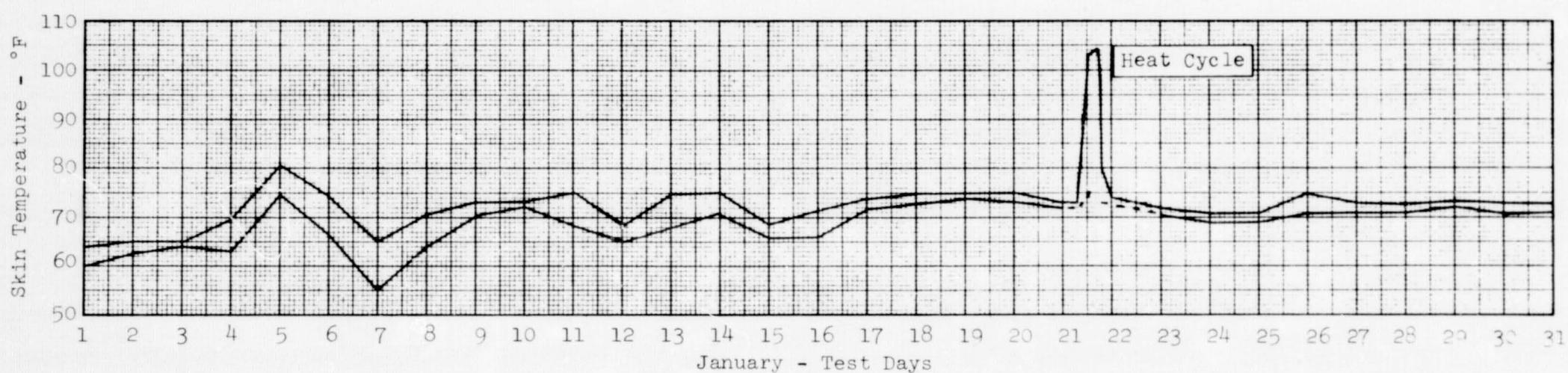
APOLLO CM FUEL TANK SN 020, ONE YEAR STORAGE TEST - MMH



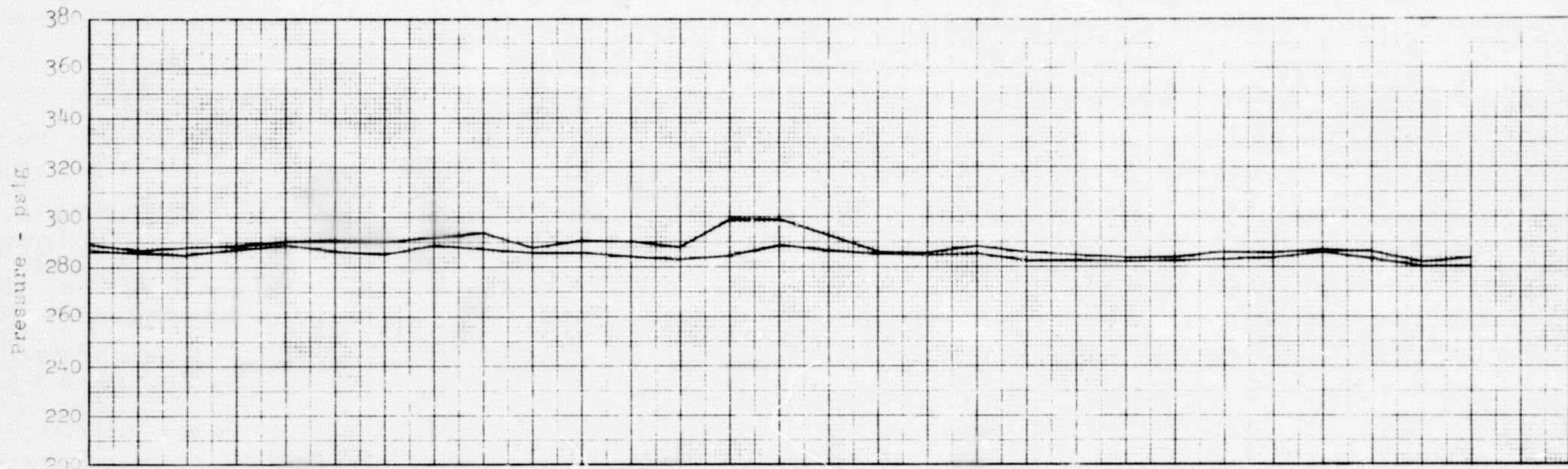
Sampled and
Drained Ullage

Flange Seal
Leak Test

Maximum and Minimum
Value Plotted For
Each 24 Hour Period



APOLLO CM FUEL TANK SN 020, ONE YEAR STORAGE TEST - MMH

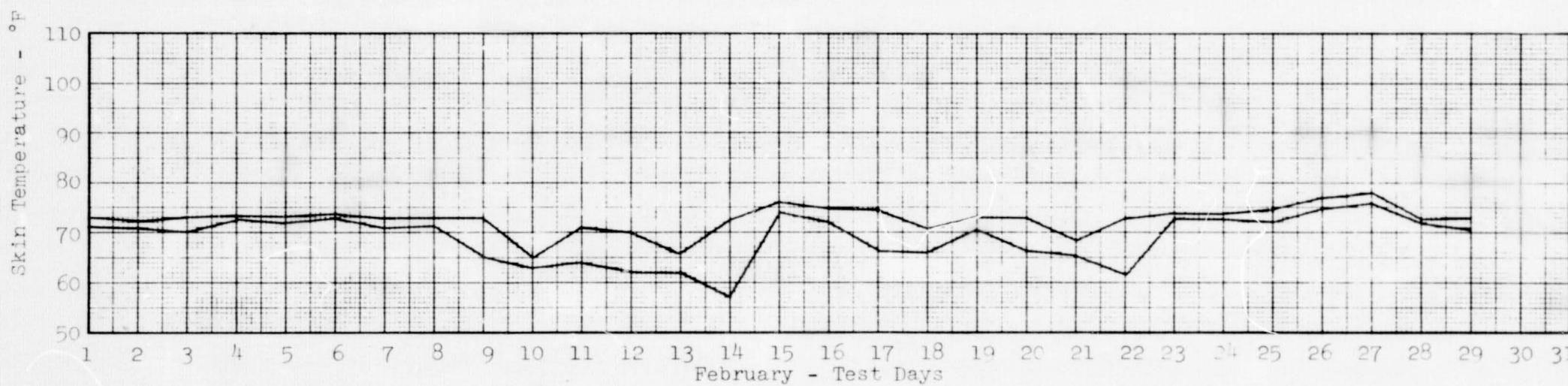


Sampled and
Drained Ullage

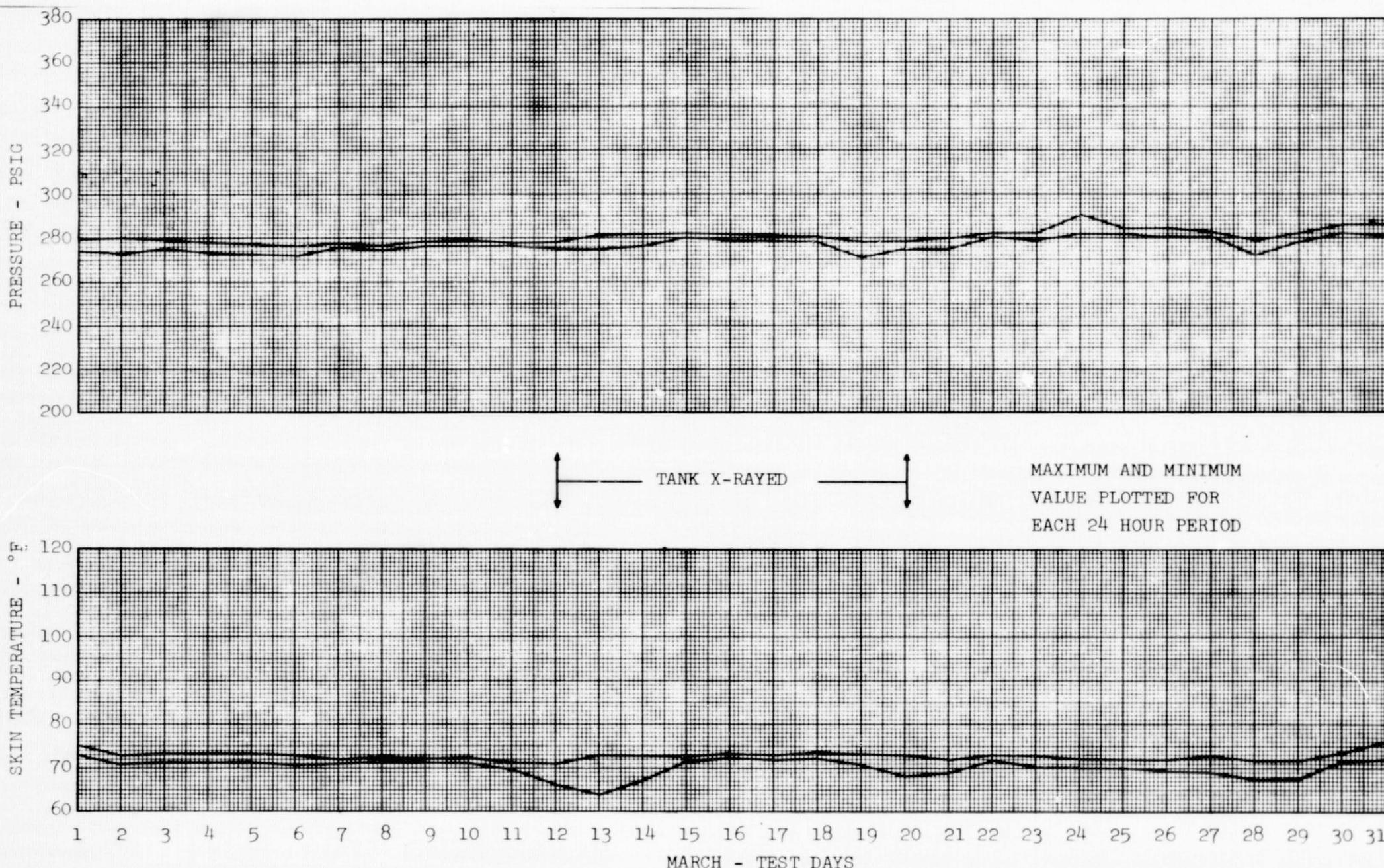
Tank
X-Rayed

Maximum and Minimum
Value Plotted for
Each 24 Hour Period

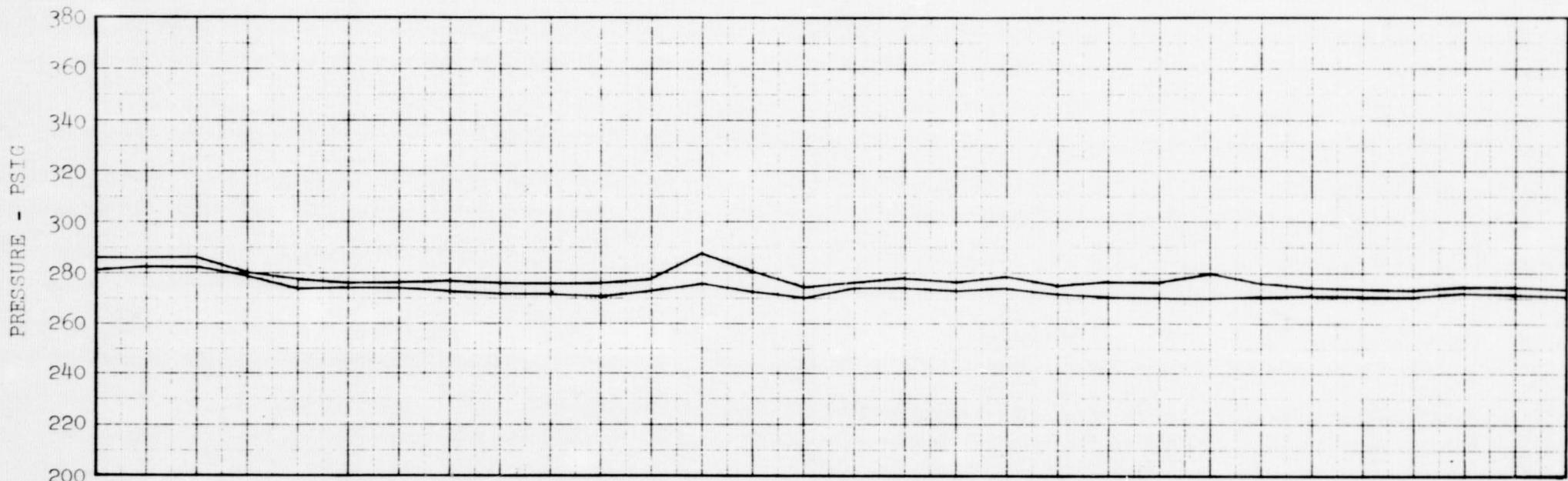
Flange Seal
Leak Test



APOLLO CM FUEL TANK SN 020, ONE YEAR STORAGE TEST - MMH



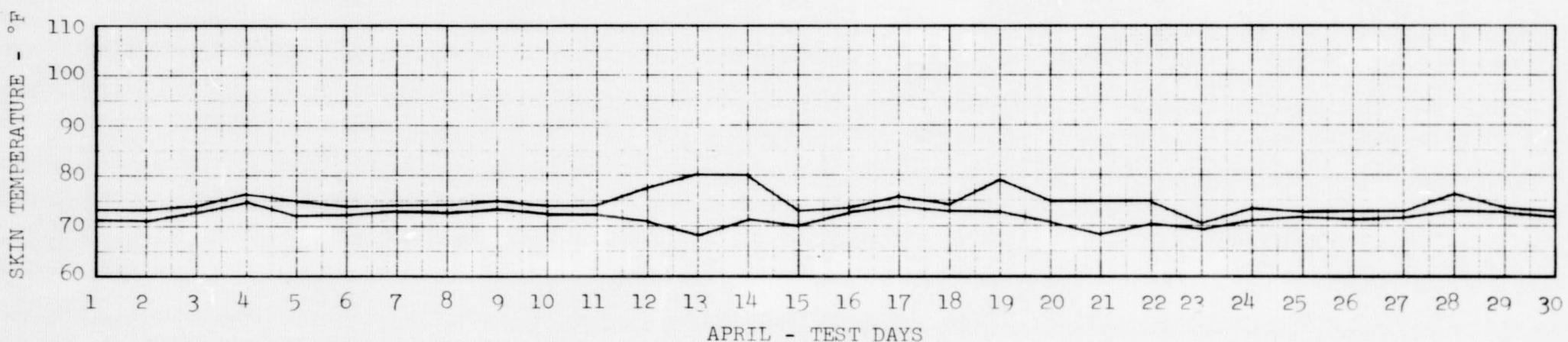
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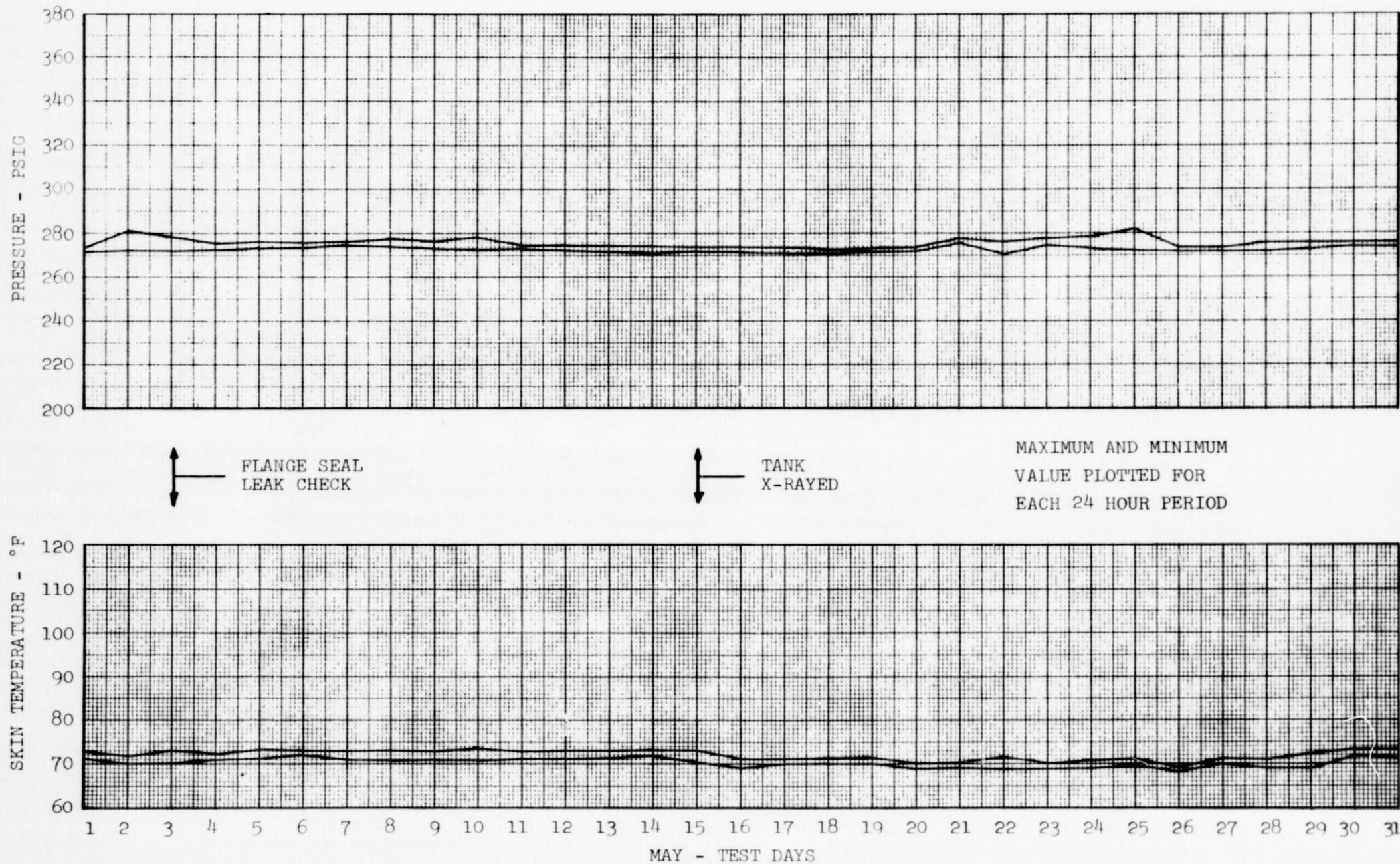
MAXIMUM AND MINIMUM
VALUE PLOTTED FOR
EACH 24 HOUR PERIOD

TANK
X-RAYED

FLANGE SEAL
LEAK CHECK



APOLLO CM FUEL TANK SNO20, ONE YEAR STORAGE TEST - MMH



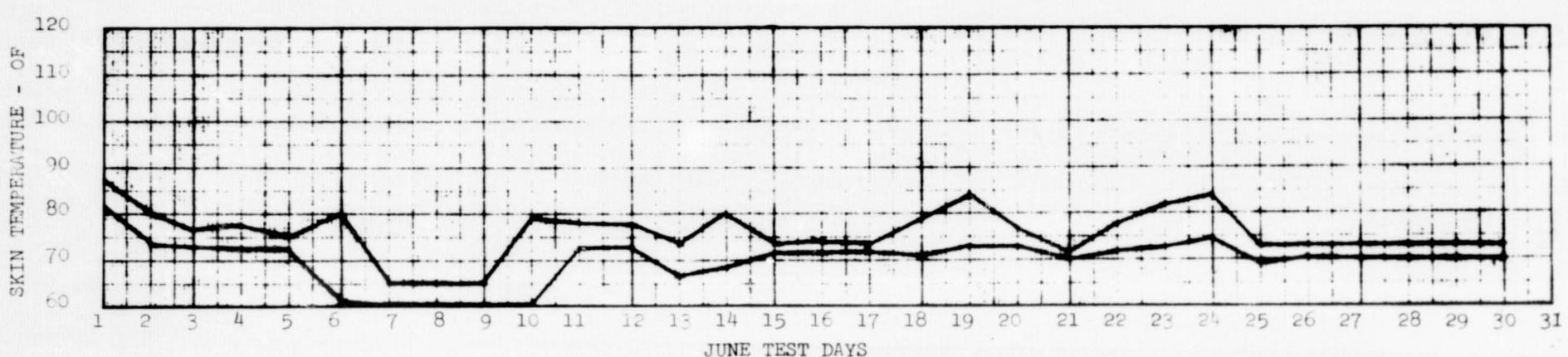
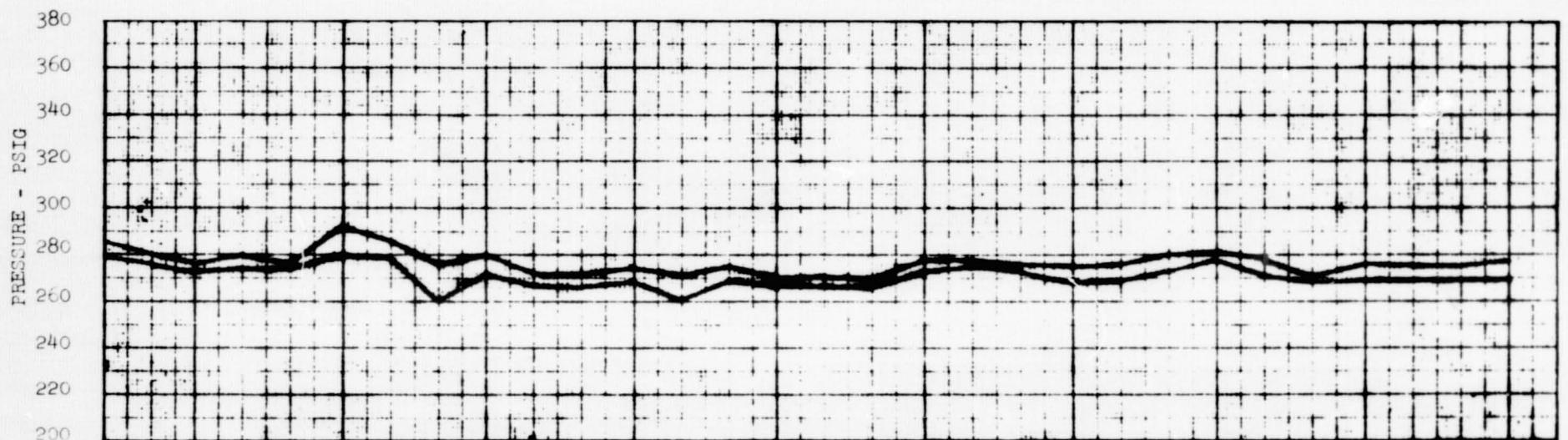
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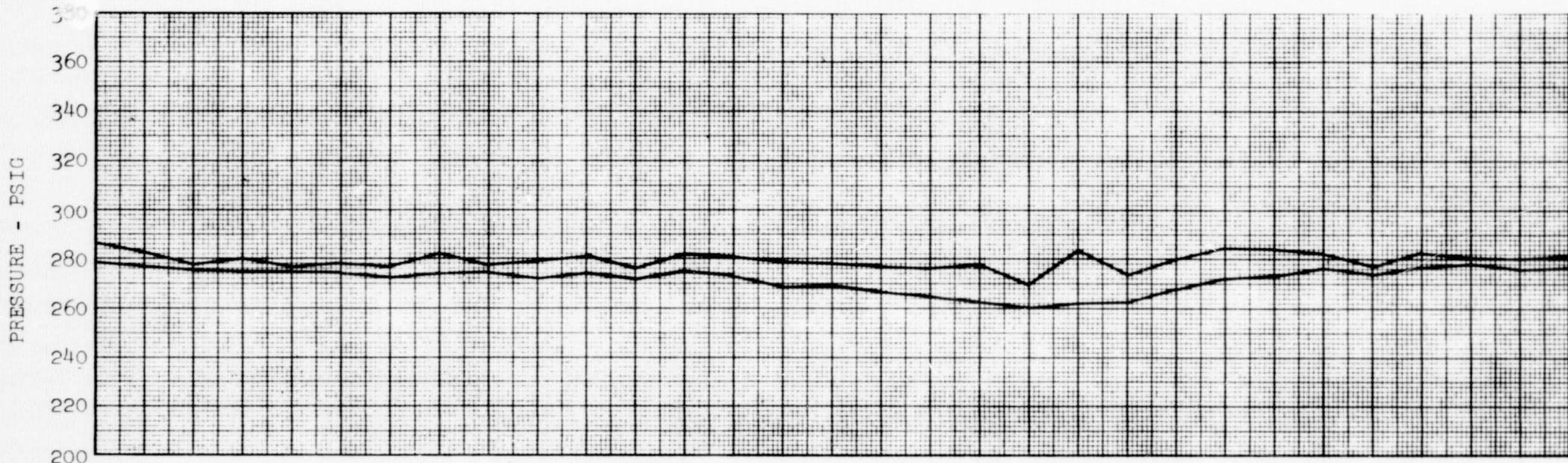
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Date _____



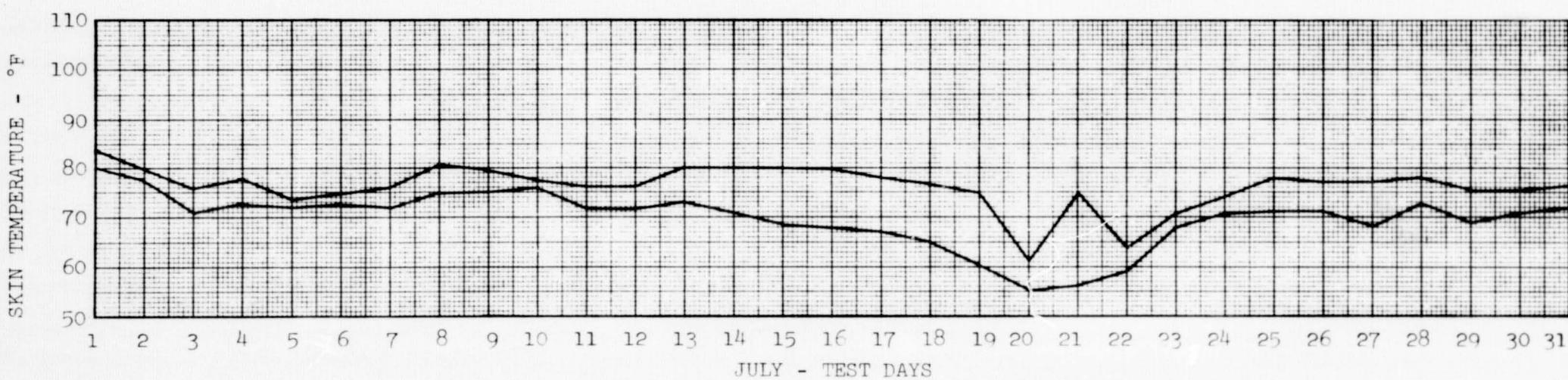
APOLLO CM FUEL TANK SN 020, ONE YEAR STORAGE TEST - MMH

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 Report 8514-928004
 Issue _____ Date _____

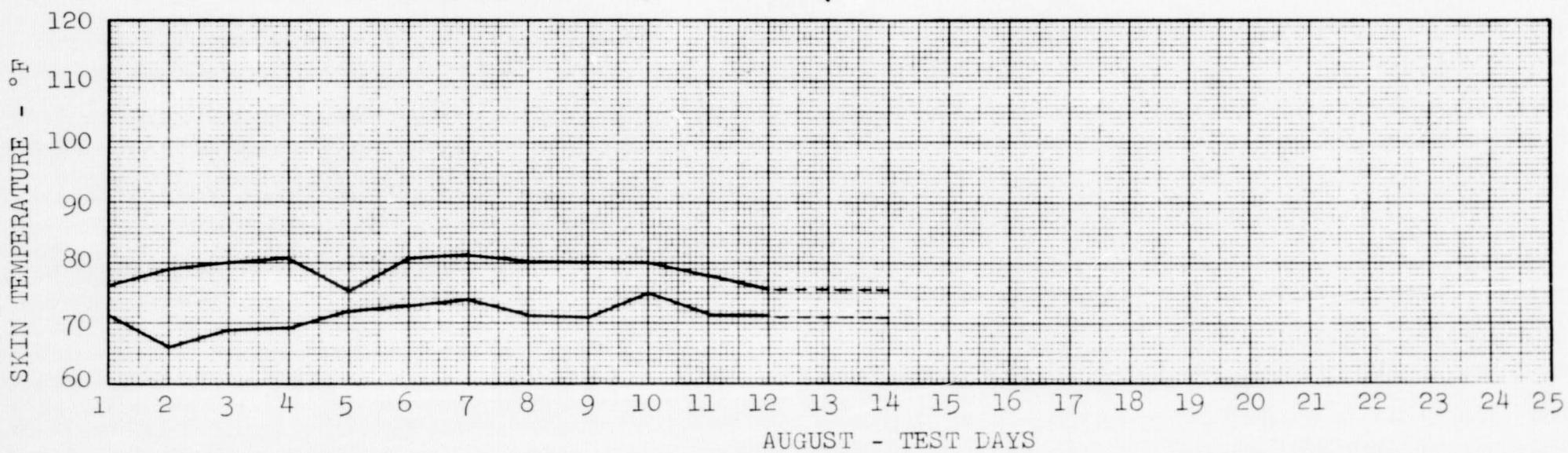
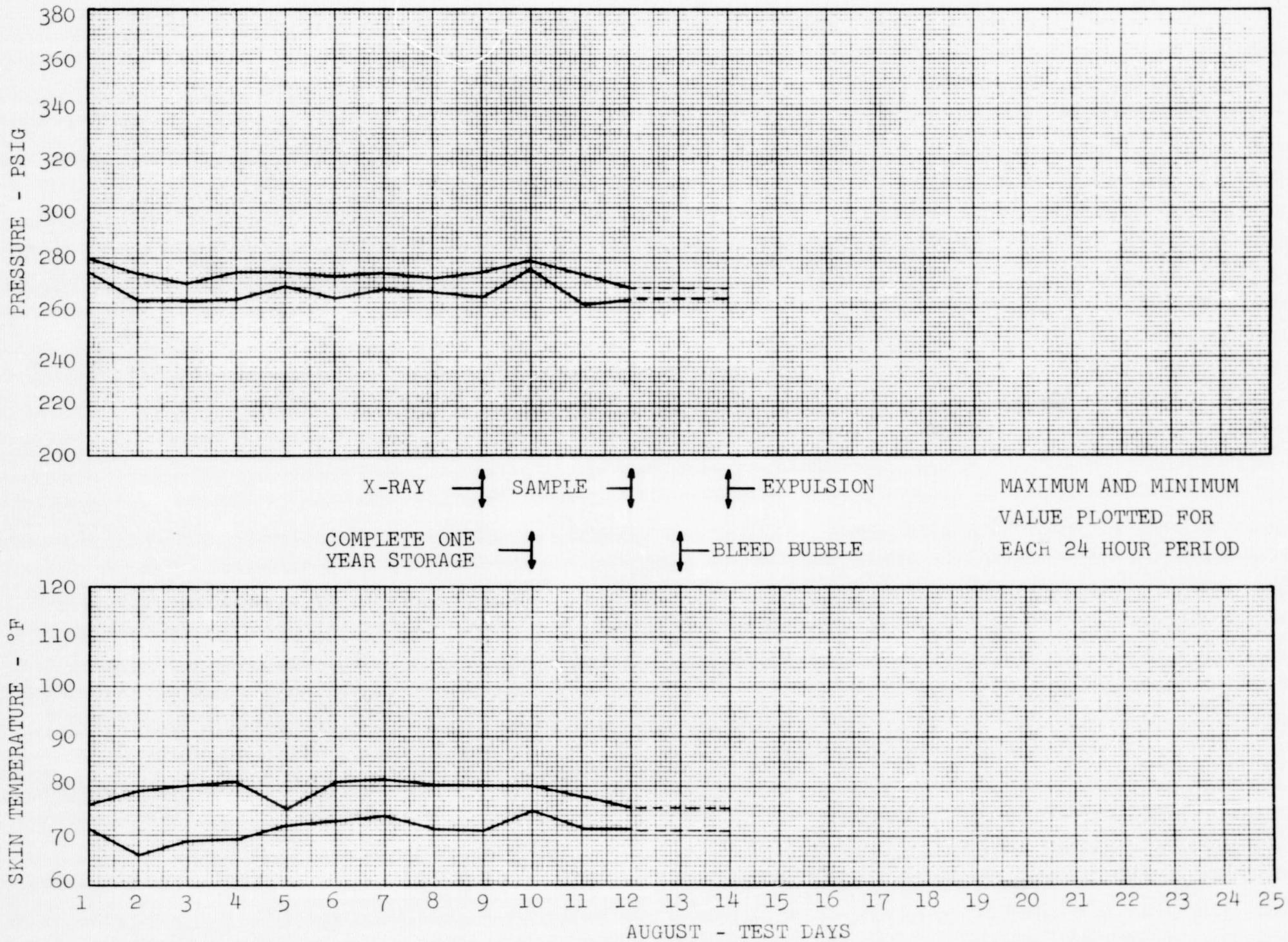


MAXIMUM AND MINIMUM
VALUE PLOTTED FOR
EACH 24 HOUR PERIOD

FLANGE SEAL
LEAK CHECK TANK
X-RAYED



APOLLO CM FUEL TANK SN 020, ONE YEAR STORAGE TEST - MMH



APOLLO CM FUEL TANK SN 020, ONE YEAR STORAGE TEST - MMH

BELL AEROSYSTEMS COMPANY
DIVISION OF BELL AEROSPACE CORPORATION

SIGNATURES

(Report Approval)

R. K. Austin
Program Manager - Model 8514
Bell Aerosystems Company

Date: 11/14/69

J. M. Thompson
Assistant Chief Engineer
Structural Systems Dept.
Bell Aerosystems Company

Date: 11/14/69

R. V. Grom
Defense Contracts
Administration Service

Date: 11/20/69